MANUAL
OF
RAILWAY ENGINEERING

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MANUAL

OF

RAILWAY ENGINEERING

FOR

The Field and the Office.

SECOND EDITION REVISED AND ENLARGED.

BY

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M. INST. C.E.

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1874.

THE object of the Author in writing this Manual was, first, to assist pupils on joining an office to understand what was going on around them; and, secondly, that it should be a book of reference in the various routine steps up to the preparation and letting of a Railway contract.

The Author in this work only deals with ordinary every-day work, leaving anything outside that to be sought in the many treatises specially written on the various subjects that a Railway Engineer may have exceptionally to deal with.

AUGUST, 1874.

CONTENTS.

PART I.

PARLIAMENTARY WORK.

ON THE PREPARATION OF PARLIAMENTARY PLANS, AND THE EXECUTION OF OTHER WORK CONNECTED THEREWITH.

In the preparation of Parliamentary plans, the work which is required of the engineer may be divided into the following operations :—

In the field,
- Levelling,
- Correcting plans,
- Referencing ;

And in the office,
- Plotting the section, and finishing up same,
- Correcting plans and proofs, &c.,
- Preparing estimate.

Though each assistant engineer, when dispatched to the country, has special directions given to him about his work, still he should have a thorough knowledge of the requirements of standing orders : and therefore extracts and explanations are here given of such of the standing orders of both houses of Parliament, as refer to the engineering part of the work necessary for obtaining a private Act of Parliament.

STANDING ORDERS (House of Commons, 1874.)

Standing orders are in two sets—one for the House of Commons, and the other for the House of Lords. They are, however, practically identical.

Where application is intended to be made in the next ensuing session of Parliament, notices of such intention must be published in the *Gazette* and in three successive weeks in some one and the same newspaper of the county in which the work is proposed to be constructed, and if it lies in more than one county, then in a newspaper of each such county *and* in a newspaper of London, Dublin, or Edinburgh, as the case may be. (S. O. No. 19.)

ORDER No. 14.—Notices by advertisement shall contain a description of all the termini, together with the names of the parishes, townships, townlands, and extra-parochial places in, through, or into which the work is intended to be made.

ORDER No. 16.—In the case of a proposed street-tramway, the notices and plans must say whether it is to be laid along the centre of the street, and if not in the centre, "then on which side of, and at "what distance from, an imaginary line drawn "along the centre of such street," and whether or not, and, if so, at what point or points it is proposed to lay such tramway, so that for a distance of thirty feet or upwards a less space than nine feet six inches, or if it is intended to run thereon carriages or trucks adapted for use upon railways, a less space than ten feet six inches shall intervene between the outside of the footpath on either side of the road and the nearest rail of the tramway.

Notice of application for a bill for a street-tramway must be posted up in the street or streets for fourteen consecutive days in October *or* November, in the way the street authorities may direct, or failing any such direction after application, then in some conspicuous position in the street or streets.

ORDER No. 20 requires that a notice be served on every person interested in any lands, or houses, affected by the proposed works on or before the 15th day of December.

ORDER No. 32 regulates the lodgment of plans and sections with the Clerk of the Peace. Two copies of the plan and section must be lodged with the Clerk of the Peace of each county in England or Ireland, or with the principal sheriff clerk of each county in Scotland, through which the line of proposed railway passes, on or before the 30th day of November.

ORDER No. 33 requires that a published map, (which in case such exists must be the Ordnance map on the scale of one inch to a mile,) to a scale of not less than half an inch to a mile, (or in Ireland to a scale of not less than a quarter of an inch to a mile,) with the general course of the proposed railway marked on it, be deposited at the office of the Clerk of the Peace or sheriff clerk, with the plans, on or before the 30th day of November.

ORDER No. 35.—If work be situate on tidal lands, a copy of plans and sections, with tidal waters coloured blue, and if a bridge over tidal waters be proposed the span and headway of the nearest bridges above and below, must be lodged with the Board of Trade on or before 30th November.

ORDER No. 36 requires that a copy of the plans and sections, together with a published map, be lodged with the Board of Trade, on or before the 30th day of November.

ORDER No. 37 requires that a copy of the plans and sections, together with a published map, be lodged at the Private Bill Office of the House of Commons, on or before the 30th day of November.

ORDER No. 39 requires that a copy of the plans and sections, of so much of the line as lies in any parish, be lodged, in England with the Parish Clerk, in Scotland with the schoolmaster of the parish, or if there be no schoolmaster, with the session clerk, and in Ireland with the Clerk of the Union, on or before the 30th day of November.

The standing orders of the House of Lords require exactly the same lodgments as those above mentioned; but, instead of Order No. 37, the Standing Order No. 182, section 10, requires that a copy of the plans and sections, together with a published map, be lodged, on or before the 30th day of November, at the office of the Clerk of the Parliaments, an office corresponding to the Private Bill Office of the House of Commons.

The number of copies that an engineer must *necessarily* provide of the Parliamentary plans and sections is—

For the use of	his own office	1
,,	the solicitor	1
,,	the promoters	1
,,	the Parliamentary Agent . .	1
For lodgment	at the office of the Clerk of the Peace.	2
,,	at the Private Bill Office . .	1
,,	at the office of the Clerk of the Parliaments	1
,,	at the office of the Clerk of the Union	1
,,	at the office of the Board of Trade .	1
		10

This number is increased, when the proposed work lies in more counties than one, or affects tidal waters.

The engineer must observe that he is required to lodge with *each* Clerk of the Peace, or Sheriff-clerk, an *entire* set of plans and sections; but with each clerk of a parish or union, only so much as affects *that* parish or union; so that one set of plans may be cut up, and the pieces serve for lodgment for all the parishes.

The number of "published maps" that are required is—

For the Engineer's Office	1
" Private Bill Office	1
" Office of the Clerk of the Parliaments	1
" Office of the Board of Trade	1
" Promoters	1
" Solicitors	1
" Office of the Clerk of the Peace	1
	7

The number of these maps is likewise increased, if the proposed work be situated in more counties than one.

ORDER No. 45.—The estimate to be deposited on or before the 31st December.

ORDER No. 48 prescribes the following form, "or as near thereto as circumstances may permit," for the estimate :—

ESTIMATE of the proposed (Railway).				
Line, No.			Whether Single or Double.	
Length of Line	*Miles.* *f.* *ch.*			
	Cubic yds.	*Price per ya.*	*£ s. d.*	*£ s. d.*
Earthworks:				
Cuttings—Rock . . .				
Soft Soil . .				
Roads . .				
Total . . .				
Embankments, including Roads . *Cubic yds.* . . .				
Bridges—Public Roads . . . *Number* . .				
Accommodation Bridges and Works				
Viaducts				
Culverts and Drains				
Metallings of Roads and Level Crossings				
Gatekeepers' Houses at Level Crsosings				
Permanent Way, including Fencing :				
Miles. *fgs.* *chs.* at	*Cost per Mile.* *£ s. d.*			
Permanent Way for Sidings, and Cost of Junctions . .				
Stations				
Contingencies . . . . per cent.				
Land and Buildings: A. R. P.				
TOTAL . . . £				

The same details for each branch and general summary of total cost.

ORDER No. 50 requires that the general plan be on a scale of not less than four inches to a mile, and that, if the scale is less than one inch to four

hundred feet, an enlarged plan on a scale of four hundred or more feet to one inch be given of every building, yard, court-yard, or land within the curtilage of any building, or ground cultivated as a garden, that is situated within the "limits of deviation" as marked on the plan.

In Ireland it is usual to make the large Ordnance map the basis of operations; it is on a scale of six inches to one mile, and, thus, within the prescribed limit of scale.

ORDER No. 52 requires that the distances from one of the termini be marked in miles and furlongs; and if any curve be proposed of a radius of, or less than *one mile* in length, the length of the radius shall be described in *furlongs* and *chains*. Also, that if tunnelling be intended, the portion of the centre line which is proposed to be in tunnelling, shall be shown by a dotted line.

The chains referred to here, and in Acts of Parliament, are chains of 66 feet.

The engineer is at liberty, afterwards, to substitute tunnelling for open cuttings; but he must make, and defend, his parliamentary estimate on his parliamentary plans and sections, irrespective of any alterations.

ORDER No. 53 requires that any intended diversion of a turnpike or public carriage-road, navigable river, canal, or railway, shall be shown on the plan, and any proposed alteration in the width of the same noted.

This only requires that any alteration for which power under the special Act is necessary shall be shown: the fact of any alteration not being shown, does not preclude the engineer

from availing himself of the provisions of the Railway Clauses Act, 8th Vic., c. 20, while on the other hand, the fact of a diversion being shown on the parliamentary plans gives no power whatever to make it without a special clause to that effect in the Bill.

ORDER No. 54 requires that in case of a junction with an authorized or existing railway, the course of such railway shall be shown for a distance of 800 yards on either side of the proposed junction, on a scale of not less than four inches to a mile.

It is to be noted that no particulars of curves of the existing or authorized railway are required to be given, nor need the plan of it be on the same scale as the plan of the *proposed* railway.

ORDER No. 56 requires that the horizontal scale of the section be the *same* as that used for the general plan, and that the vertical scale be not less than one inch to one hundred feet. Also, that a datum line be shown and described.

The datum line represents an imaginary level, by a certain vertical height above which every point that is required to be fixed is determined. The datum line must be the same throughout the section, and its position defined with reference to some *fixed* point *near* one of the termini.

Key-stones and parapet stones of bridges, and cills of doors of public buildings, are used as points of reference for a datum line; but not only must the point of reference be fixed, but the description of it must be minute and unmistakable.

If the proposed work be a deviation from previously authorized plans, the datum level should be referred both

to the point of reference of datum of original plans, and *also* to a fixed point near one end of the proposed deviation.

The distance of the point of reference of the datum should not be more than about one thousand feet from one terminus, and the nearer it is the better.

ORDER No. 58 requires that the line representing the railway shall be the upper surface of rails.

ORDER No. 59 requires that the distances along the datum line be marked in miles and furlongs, to *correspond* with those on the plan; that the height from datum shall be figured at each change of gradient, and also the rate of inclination of each such gradient marked.

ORDER No. 60 requires that the vertical height from the rails to the surface shall be shown wherever the railway crosses any turnpike or public carriage road, navigable river, canal, or railway: also, that if the railway be proposed to be carried over any turnpike or public carriage road, navigable river, canal, or railway, the height and span of *every* arch of all such bridges shall be marked in figures on the section; and that if any turnpike or public carriage road, or railway, be proposed to be crossed on the *level*, it shall be stated whether with or without alteration.

ORDER No. 61 requires that, if any alteration be intended in the water-level of any canal, or in the level or inclination of any turnpike road, public carriage road, or railway, the same shall be stated on the section, and each such alteration shall be numbered, and cross-sections, with corresponding numbers, shown.

The cross-sections, above referred to, must be on a horizontal scale of not less than 330 feet to one inch, and a vertical scale of not less than 40 feet to one inch, showing the present surface, and intended alteration, and the greatest inclination of each, *in figures* along those surfaces.

If a road, canal, or railway, be proposed to be crossed by a *bridge*, without an alteration in its level, no cross-section need be shown; but if a *level* crossing of a public carriage road be intended, a cross-section must be shown in any case.

Cross-sections must extend to a distance of at least two hundred yards on each side of the centre line, as it is shown on the general plan.

ORDER No. 62 requires that the height of any cutting or embankment, and of each portion of a cutting divided by a tunnel, and of each portion of an embankment divided by a viaduct, be shown *in figures*, if same exceed *five feet.*

ORDER No. 63 requires that tunnelling, or a viaduct, if intended, be shown on the section.

It is usual to describe tunnels and viaducts in writing, as well as to mark their position on the section.

ORDER No. 64.—When a railway is intended to form a junction with an existing or authorized railway, the gradient of the latter shall be shown on the deposited section, *and in connection therewith*, and on the *same* scale as the general section, for a distance of 800 yards on either side of the point of junction.

No gradient heights, marks of change of gradient, or rates of inclination, are required to be marked.

LEVELLING.

In Parliamentary work time is always of great value, and accordingly the line of railway, if of any great extent, is divided into sections of six or eight miles in length, to each of which is appointed an assistant engineer to make the section, and another to correct the plans.

Of course it is according to the time available that the engineer-in-chief determines on the length of such sections, and the advisability of employing one, or two, assistants on each section.

The assistant engineer who is charged with the execution of the levelling, having provided himself with a set of Ordnance maps, marks, with the minutest accuracy, the centre line as laid down by the engineer-in-chief, and having received his instructions, starts for the country.

Every morning, before commencing work, he should examine his level, and see whether it is in adjustment or not, as not only may very valuable time be saved by this precaution, but he may be enabled to give sworn evidence as to the accuracy of his work should the Bill be opposed on standing orders.

Of the adjustments of the level nothing need here be said; they will be found in many books on that particular subject. The author is of opinion that on account of the *speed* and *certainty*, both of *detecting* and *adjusting* any errors, preference is to be given to the Y level for this work. The testing and adjusting of a dumpy, if out of adjustment, occupy much time, and never give the thorough confidence that an engineer should have in a level, and which he *can* have in a Y level.*

* The reader is cautioned against placing any reliance on the "three stakes" process of adjusting a dumpy level usually given in books, which is completely fallacious, as admitted by Mr. Gravatt himself in a letter to the author.

At starting, and about every mile along his portion of the line, the engineer should fix on a good bench-mark, to serve in checking his own work, and also for reference for any engineer appointed to re-level the same ground: with a view to the latter proceeding, each bench-mark should be unmistakably described in the level book.

Should the division the engineer is engaged on be the terminal one nearest the datum point of reference, he should start from that point.

The engineer then proceeds to level along the line, as shown by the Ordnance Map. He must determine the position of each sight with reference to fixed points on the map, such as intersections of fences, houses, limekilns, roads, &c. As a *general* rule he should take a sight near each fence, and intermediates wherever the contour of the ground varies from a straight line by two feet.

Where the Ordnance map is well filled in, and the country ordinarily smooth, ranging rods are not required; but in the cases of rough side-long ground, or where the filling in of the map is deficient or incorrect, they are indispensable.

The best scale with which to measure distances on an Ordnance map is one cut off that particular map; but for all purposes of field work, a scale such as is made by Elliott, called a "shrunk Ordnance" scale, is sufficiently accurate. These scales are graduated from an average of Ordnance sheets, and for the six-inch scale are about 5.925 inches to one mile. A scale graduated to 80 to an inch is the most convenient of ordinary scales for using with the six-inch Ordnance map, each division representing 11 feet.

The engineer must not expect to find all the fences correct on the Ordnance map, and as he is always sent out to level before the maps are corrected, he must be careful not

to be led astray by new fences, or the omission or removal of old ones. Some of the Ordnance maps are very deficient in the filling-in; but this is gradually being remedied.

The engineer should note in his field book everything that may occur to him as likely to be of use, such as the nature of the ground, as moor, red bog, clay, gravel, or rock, and the *kind* of rock; the size of streams and rivers, the size of existing bridges and culverts, the height of floods, &c., &c.

As in parliamentary levelling, the centre line is not usually chained, the engineer must give in the column headed "distance" in his field book, some means of referring to the position of each observation.

This may be effected by marking the points on the map with either letters or figures, and entering the same opposite the respective sights in the field book. Where sights are taken at points intermediate, or badly defined on the map, their position must be marked by entering the measured distance from the nearest well-determined point.

The engineer will do well to mark in these numbers or figures on his plan, with carmine or lake, in the evening. This does not spoil the map for other purposes, as the carmine can be totally removed by the application of a solution of chloride of lime.

The column in the field book, headed "reduced level," should not be filled in until the datum level is fixed; yet the engineer should reduce his book before commencing his check-levelling. For this purpose he should rule off a column on the margin of the right-hand page, in which to reduce his levels to an arbitrary datum for comparison with the check levels. In this column no reduced levels need be entered for intermediate sights, nor for any sights in a page in which no sight on a *bench-mark* occurs. Without

causing the least delay, the engineer will find that he can fill up this column in the field as he goes on.

If the engineer has his book so reduced, he can instantly, on getting the reduced level of the datum from the assistant before him, hand it on to the next.

Having completed the levelling of the centre line, the engineer returns over his bench-marks, checking the levels of *each*. The errors in checking should not be more than one-tenth of a foot in one mile; if a greater error occurs, the levelling should be repeated between the bench-marks where it has been detected.

He next proceeds to make the cross-sections, *i.e.*, sections along roads which cross the centre line of railway, and sections of diversions of roads, canals, or railways.

Except he receives special instructions to the contrary, he should make a section of *every* such public road that he meets for 200 yards on each side of the centre line, as he cannot at this stage tell whether a level crossing be not proposed at that road, in which case a section is always necessary, or whether the gradients will admit of its being passed over, or under, the railway with "level unaltered."

Standing orders do not require sections of diversions of roads, even when proposed to be altered; nevertheless, they are generally given, if any alteration in gradients be contemplated, and *must* be given if the diversion be one that is to be specially authorized by a clause in the Bill.

The distances, in making cross-sections, should always be measured with a chain or tape.

Where there is a branching road within 200 yards of the centre line, the section should be made along each such branch, as shown by the cross-section, No. 2, Plate 1.

CORRECTING PLANS IN THE FIELD.

The best available maps of the district are taken as the basis of the plan; and it is the duty of one assistant, as mentioned before, to correct the map in the field, and finish it up, and prepare it for the lithographer, in the office.

The assistant appointed to correct the plans first marks on his maps the centre line very exactly, and also the limits of deviation, as directed by the engineer-in-chief, and then proceeds to the country.

He then walks over the ground, examining *every* field, and house, any part of which is within limits, and corrects the map by marking in all new fences, and crossing out all fences which have been thrown down since the date of the map he is using.

If the map is deficient, he must survey in whatever details are wanting.

Fences that have disappeared should be *crossed out* on the map, and not *erased;* and new fences should be inserted with *red ink*, and not with Indian ink. This method of proceeding is important, as it insures no *correction* being overlooked, when the maps for the lithographer come to be prepared.

He must also prepare enlarged plans of any *house* or *garden*, any part of which is inside the limits of deviation.

These enlarged plans are usually prepared on a scale of 300 or 330 feet to one inch; but sometimes, as in passing through a town, where the houses are numerous, a much larger scale is used with advantage.

Enlarged plans should be given of any limekiln, or building of any kind, even of ruins of which only part of the walls are standing.

The limits of deviation are usually marked at a distance

of 300 feet on each side of the centre line; but are contracted in passing through towns, and, occasionally, through valuable land, or ground that must be avoided in order to prevent opposition.

The limits are often put at *more* than 300 feet; but then they are not strictly limits of *deviation*, though still so called, as, by 8th Vic. c. 20, sec. 15, the centre line can nowhere be deviated more than 300 feet in open country, and 30 feet in ground continuously built upon; but by so extending the limits compulsory power of purchase may be obtained.

CORRECTING PLANS IN THE OFFICE.

Having returned to the office with his field maps corrected, the assistant sets to work, and prepares a correct plan for the lithographer to work from.

He first marks the centre line and limits of deviation, as directed, and also lines showing how much of the plan is to be lithographed; for though standing orders require nothing to be shown outside limits, it is usual to show an inch wide or so on each side.

Perhaps the best plan is to cut out so much of the map as he wishes to have lithographed, and mount it on a separate sheet of paper, in the position he wishes it to occupy when lithographed. Errors in the parts shown outside limits of deviation are of no consequence.

He now carefully *erases* any fences or houses which he has crossed out on his field map, and inserts in black all new fences and houses. The object of having made his corrections in *red* is now evident.

He now plots each enlarged plan, somewhere near its position on the general plan, indicating its position by

writing, or by a direction line; both methods are shown on Plate 1; the former above and the latter below the general plan.

On these enlarged plans the centre line and limit of deviation on that side of the centre line on which the house or garden is situated, must be shown.

If the assistant has cut out the portion of the Ordnance sheet which is to be lithographed, he must carefully make out, and print in their proper places, the name of each townland, parish, and county; and at every parish or county boundary describe the same in writing.

Townland boundaries need not be described in writing.

He must also make out for the solicitor a list of such townlands, parishes, and counties, and take the greatest care to make such list perfect, as an omission in it might be a fatal objection to the bill. (See Opposition S. O. *infra.*)

He next proceeds to mark each enclosure, house, river, and road, with a number of its own.

These numbers need not be consecutive, and may be repeated, by townlands, or by parishes. A number must not be repeated in the *same* townland or parish, as the case may be, except with an affix attached, as 17a, 17b. If a number has been put in by mistake, it may be erased. The numbers need not be consecutive.

In the case where a townland or parish boundary runs along the *middle* of a road or river, the road or river must have a distinct number in each townland.

If *possible*, every number should be shown on the general plan; but sometimes the divisions are so minute that the numbers cannot be distinctly inserted, and as this always occurs in a place where an enlarged plan is required, a note is usually put on the plans, to the effect that "when the divisions are too minute to allow of the numbers being

inserted on the general plan, they are shown on the enlarged plans."

The words "limit of deviation" should be written on *each* limit at *each* end of the sheet, and also on the limit, or limits, as shown on each enlarged plan.

The boundaries of townlands, parishes, and counties may be given in the same character as that which is used on the Ordnance map.

The miles and furlongs should be marked and figured.

If the radius of any curve be of, or less than, one mile in length, its length in furlongs and chains should be written either along the curve or at right angles to it.

If any road, railway, river, or canal be proposed to be diverted, the general course of such diversion should be shown by dotted lines, and the words "proposed deviation of road," or river, written along them.

If tunnelling be proposed, the centre line for that length must be dotted.

Scales *need* not be given at all; but they always are, either on every sheet, or on the first page only, and sometimes on the title-page only.

THE SECTION.

When the engineer, who has made the section, has reduced his book to the proper datum, he plots his section in the office. In doing this he must take his distances from the maps which he has been using in the field, and must see carefully that they correspond with the distances on the copy of the plans which is prepared for the lithographer.

Maps differ greatly in shrinkage, and it is quite necessary that the position of the roads, &c., on the section, as

referred to the miles and furlongs, as well as the lengths of the miles and furlongs themselves, should *exactly* agree with the plan *when lithographed.*

He next puts on the gradient lines, under the directions of the engineer-in-chief.

The object being, generally, to make the estimate of the line as light as possible, subject to a ruling gradient, the gradients should be laid, *ceteris paribus*, so as to make the quantities in the cuttings as nearly as possible equal to the quantities of the neighbouring embankments.

While laying down the gradients the engineer must look to everything that may affect the cost of the work, such as heights of floods, sections of roads crossed, and the practicability of under or over bridges.

He must also keep in mind the positions of intended stations, and there provide for horizontal or easy gradients, for 700 or 800 feet at least.

He must remember that the gradient line represents the top surface of rails, and consequently that an embankment will appear considerably larger than a cutting which contains the same number of cubic yards of material.

The introduction of tunnels, and their lengths, should be determined on with a view to the great desideratum of a minimum estimate. The simplest case is where a tunnel is substituted instead of a cutting *which would be run to spoil.*

Let h be the height of the cutting in feet,

b the base in feet,

r the ratio of slopes,

p the price per cube yard of excavation,

P the price per yard run of the tunnel;

and it follows that where the amounts are equal,

$$h = \sqrt{\frac{9 \times P}{p \times r} + \frac{b^2}{4r^2}} - \frac{b}{2r}$$

and that in any deeper cutting the tunnel is cheaper, and *vice versa.* If, however, the cutting be required to make up an embankment, the engineer must not forget to charge against the tunnel the cost of side-cutting necessary to replace the cutting.

Having put on the gradients, he must see that Standing Orders are complied with in the following particulars :—

Heights of cuttings and embankments must be marked, if exceeding five feet.

The inclination of each gradient, and the gradient heights must be given.

Public roads, &c., must be marked, and the manner in which the railway will affect them, and also the height of embankment or cutting at *every* road.

Under-bridges must be described as to span and height.

A description, clear and unmistakable, must be given of the datum level.

The miles and furlongs must be marked and numbered.

Viaducts and tunnels must be marked, if proposed.

Cross-sections of every road *altered* for the purpose of being passed over or under the railway, must be given.

Cross-sections of all proposed level crossings, whether the road be proposed to be altered or unaltered, must be shown.

A section must be given of any existing or authorized railway which it is proposed to form a junction with.

The description used in the case of roads, affected in different ways, is shown in Plate I.

The amount of alteration in the level of a road will depend on the kind of bridge that the engineer proposes to himself for each case.

If the bridge be an over one, that is, one carrying the road *over* the railway, the height, supposing, as is usually the case, that it is to be constructed for a double line of rails, from the top surface of rails to highest point of road, will be, according to the author's practice, for a stone bridge, 19 feet 6 inches, and for an iron bridge, 16 feet 9 inches.

These are the general heights, but they will vary with the height of the chimney of the engines proposed to be used.

If the bridge is to be an under one, the height from the road surface to top surface of rails will be—

For a public road, if the bridge be stone,		22 ft.;	if iron,	17 ft. 8 in.
For a turnpike road,	,,	23 ft.;	,,	19 ft. 8 in.
For a private road,	,,	22 ft.;	,,	16 ft.

These are the usual heights adopted, but they may by special designs be somewhat reduced, but as a rule, except in the case of city railways, it is not necessary to go into such detail at this stage. (See *infra*, under "Contract Work.")

The altered inclinations shown on the cross-sections, except there be special reasons to the contrary, should be at least equal to the inclinations laid down by the Railways' Clauses Act, namely—

For a turnpike road, . .	1 in 30.
For a public road, . . .	1 in 20.

In Ireland every mail-coach road is considered as a turnpike road.

If engineering difficulties prevent these heights and inclinations being given, the fact must be mentioned in the *Bill* as well as shown by the cross-sections, or otherwise they cannot be so carried out.

Parliamentary plans and sections are "per se," only binding or of authority as regards the centre line of railway, limits of deviation, and level of rails.

LITHOGRAPHING.

The plan and section having been finished, tracings are most carefully made and furnished to the lithographer, who shortly after sends to the engineer a *first* proof. The lithographer will undertake the tracings himself; but it is the more satisfactory plan to have them made in the engineer's office, if convenient.

The engineer now compares the proof with the original, and marks all corrections prominently in red ink, and returns it to the lithographer, who afterwards furnishes a *second proof.* Having corrected the second proof, an assistant from the engineer's office should attend in the lithographer's drawing office, and *see* these second corrections put on the stone. He will thus save, what is generally most important at this period, *time*, as he can examine, and correct the next proof as soon as it is "pulled;" and if it be right, give the order to print at once, saving the delay of interchanging proofs, and of shifting the stone.

Some one from the engineer's office should attend, and watch the printing, examining the sheets occasionally; this is necessary to avoid two errors that corrected stones are liable to, viz.:—lines that have been erased will sometimes re-appear *during* the printing, and lines that have been in-

serted will sometimes not "come up." In either of these cases he should get the lithographer at once to retouch the stone. If this be not attended to, one great object of lithographing is lost, that is, the certainty of a perfect identity in all the copies.

When the copies are printed, they should be *again* compared with the original, and all corrections marked prominently in red on one copy, to be called the "office copy," and with which every copy before issue should be carefully compared.

Even though the greatest care has been used all through, there will be found some mistakes at the end.

REFERENCING.

The engineer has not *necessarily* anything to say to referencing, it being often undertaken by gentlemen who combine with the other requirements sufficiently accurate knowledge of the engineering part to dispense with the assistance of an engineer; but as the duty detailed below will often be thrown on an engineer, it is thought best to treat it as a matter of course.

In accordance with Standing Orders, a book of reference must be prepared by the solicitor, and lodged with the plans on or before the 30th November.

This book must contain each number that is shown on the plan, with a description of the property it refers to, and the names of all persons interested in any way in it.

It is the solicitor's business to make out this book, and for this purpose he despatches an assistant to the country to make inquiries.

This assistant sometimes requires an engineer to accom-

pany him to point out the lands, and to see that the num bers, and descriptions in the book of reference correspond with the same on the plans.

If the lithographed sheets are ready, of course the engineer takes a copy of them with him, and besides his special business as a guide to the solicitor, keeps an anxious eye out for mistakes in the plan, which there may be still time to have corrected.

Should time press, and the engineer be unable to get the lithographed sheets, or even corrected duplicate proofs, he must put the numbers and limits on the same maps as were used in the field previously, exactly as they are on the copy furnished to the lithographer.

During the referencing, numbers may be struck out or inserted, if required. If new numbers are inserted, it will be more convenient if they are formed by different affixes put to numbers belonging to the *same* owners. All such alterations should be *prominently* marked.

When the fair copy of the book of reference is made out, and the plans ready, they should be again compared, and both numbers and descriptions checked.

The plans being now ready, are labelled, and handed over to the solicitor for lodgment, *and a receipt obtained from him.*

ESTIMATE.

The engineer next proceeds to make out the estimate, which must be lodged on or before the 31st December.

From the section he takes out the quantities of the embankments and cuttings. The notes of the engineer who prepared the sections, with borings if thought necessary, enable him to separate the rock from the clay cuttings.

The reader is referred for details of the method of taking out quantities to the second part of this work. The preparation of the estimate is there more minutely described than it would be in this place, greater particularity being required in contract work.

Where *less particularity* is said to be required, it does not mean that *carelessness* will be excused; but that *time* must not be wasted on minute details, when such are out of place.

The *form* of estimate is given under Standing Order No. 48, *supra*.

The "length of line" should be the same as shown by the section.

The "earthworks" will be calculated in a similar manner to that described further on under the head "Contract Work."

The "bridges" for public roads are usually estimated from the known cost of similarly situated works.

The accommodation works must be estimated by the engineer's practical acquaintance with the expenditure under the same head on similarly situated railways. The same observation applies to the next four items, and to the amount to be allowed for sidings, junctions, and stations.

Permanent way, including fencing, is estimated at a price per mile.

The items which make up the cost of permanent way are :—

Iron rails	at —— per ton.
Chairs	at —— per ton (if any.)
Fastenings	at —— per ton.
Fishplates	at —— per ton (if any.)
Royalty	at —— per ton (if any.)
Sleepers	at —— per sleeper.
Ballast	at —— per cubic yard.
Fencing	at —— per lineal yard.
Laying	at —— per lineal yard.

Land is valued by a professional valuator, and the cost introduced by the engineer. In case of opposition, the valuator must prove the value of the land before the committee.

When the total is brought out, 10 per cent. *at the least* should be added for contingencies and law and engineering expenses.

If the country be a very easy one, and the estimate consequently small, 10 per cent. is not sufficient to cover law and engineering expenses, as well as contingencies; the proper per-centage is to be settled by the engineer-in-chief.

The estimate must be signed by the engineer.

The examiners may admit affidavits in proof of the compliance with Standing Orders, and it is therefore usual to forward to the Parliamentary agent the engineer's affidavit of his having signed it. Such affidavit may be sworn before *any* Justice of the Peace in England, before any Justice of the Peace, Judge, or Assistant Barrister in Ireland, or before any Sheriff-depute or his substitute in Scotland.

This appears merely to refer to the country the engineer may be in at the time, and in no way to the situation of the work.

LABOURERS' HOUSES.

Should the railway pass through a thickly-inhabited place, so that in any one parish thirty houses within limits belong to the labouring classes, a statement to that effect must be lodged before the Bill enters the House of Lords; the engineer should make himself acquainted with all such cases, as he has to make an affidavit of there being, or not being, thirty houses affected as above.

END OF PART I.

PART II.

CONTRACT WORK.

ON THE PREPARATION OF DETAILED PLANS AND SECTIONS, WITH BRIDGE DESIGNS, PREVIOUS TO THE LETTING OF THE CONTRACT.*

AFTER the Bill has become an Act, and the engineer-in-chief has received instructions from the company to proceed with the contract surveys, he reëxamines the plans, profiting by all the knowledge gained during the preparation of the Parliamentary plans, and makes what alterations may seem advisable to him, keeping, of course, within the limits prescribed by the special Act, and by the general Railways' Clauses Act, 8th Vic., cap. 20, which is set forth as follows at considerable length, as a knowledge of what it allows and what it prohibits is most essential to the engineer.

* Contracts are occasionally entered into by which the contractor is bound by the Parliamentary plans and sections, with their legal deviations, he undertaking to execute all works to the satisfaction of the engineer, and to execute all accommodation works which the company may become liable for the erection of. This is a most undesirable method of doing business, for all parties.

RAILWAYS' CLAUSES ACT.

This Act takes the place of "Standing Orders," as (coupled with the private Act authorizing the project) the guide of the engineer in getting up his work, so as to avoid all technical objections and opposition.

As regards the survey and general engineering of the work, the Railways' Clauses Act affects the engineer as follows :—

CLAUSE No. 7 enables the company in case of any omission or mistake with regard to any lands, to have same remedied by the process described. This would apply to the case where reference has been entirely omitted, and where, without this clause, no compulsory power of purchase could be exercised, and, which concerns the engineer, no compulsory entrance effected.

CLAUSE No. 11 prescribes the limits within which the level of rails at any point may be altered from the Parliamentary height, *without* the consent of those interested. In open country, the variation may amount to *five feet* either higher or lower ; and in land continuously built upon, *two feet.*

With the consent in writing of all interested, the variation is not limited by this clause, though it may be indirectly by clause 14.

It must be particularly noticed, that this variation is not to be estimated as one in the height of *embankment*, or depth of *cutting*, at any particular spot, but as a variation from the height of the rails *at that point over the datum line* referred to in the Parliamentary plans.

If the effect of the alteration is to construct the line at any point with a lower embankment, or viaduct, the varia-

tions may exceed the five feet, or two feet, as the case may be; the requisite headway for bridges over roads, &c., being left.

This does not apply to cuttings, in which greater variations than five feet and two feet respectively cannot be legally made without consent of all interested; the reason probably being to prevent the facility for making accommodation bridges being affected.

When the consent, as above, has been obtained, further steps are necessary to *legalize* the variation, as pointed out in—

CLAUSE No. 12, which requires that public notice of such alteration be given by advertisement; and, if any objections be made, the question is to be decided by the Board of Trade.

CLAUSE No. 13 requires that tunnels and viaducts, when marked on the Parliamentary section, shall be made, and made of the *length* there shown, excepting, that in the case of a tunnel it may be dispensed with, with concurrence of all interested.

This clause appears to be very stringent as regards viaducts, but the author has never known it enforced, though he is aware of numerous instances where viaducts shown on Parliamentary plans have never been constructed.

CLAUSE No. 14 authorizes the substitution of tunnels for cuttings, and viaducts for embankments, a certificate having been previously obtained from the Board of Trade, that such alteration is "consistent with the public safety, and not prejudicial to the public interest." This clause also limits the alteration of gradients and radii of curves. Gradients of, or steeper than 1 in 100, may be

altered for the worse not more than three feet per mile, and gradients less steep than 1 in 100, ten feet per mile. The radius of any curve greater than half a mile, may be lessened to one half-mile, but no sharper curve can be altered for the worse.

The limits to which the engineer may go in altering gradients are shown in the following table :—

Parl. Gradient.	May be changed to.	Parl. Gradient.	May be changed to.	Parl. Gradient.	May be changed to.
1 in 50	1 in 48.6	1 in 95	1 in 90.1	1 in 400	1 in 227.6
1 in 55	1 in 53.3	1 in 100	1 in 94.6	1 in 500	1 in 256.8
1 in 60	1 in 58	1 in 110	1 in 91	1 in 600	1 in 280.9
1 in 65	1 in 62.7	1 in 120	1 in 97.7	1 in 700	1 in 300.9
1 in 70	1 in 67.3	1 in 130	1 in 104.3	1 in 800	1 in 318.1
1 in 75	1 in 71.8	1 in 140	1 in 110.7	1 in 900	1 in 332.8
1 in 80	1 in 76.5	1 in 150	1 in 116.9	1 in 1000	1 in 345.5
1 in 85	1 in 81.1	1 in 200	1 in 145.1	Horizontal	1 in 528
1 in 90	1 in 85.6	1 in 300	1 in 191.3		

A curious point may be here noticed, resulting from the regulations of this clause, that if the gradient on the Parliamentary plans be 1 in 100, it can only be altered to 1 in 94.6; yet if the gradient be 1 in 101, it can be increased to 1 in 84.8. Hence it is advisable to introduce gradients of 1 in 101, in preference to 1 in 100, in Parliamentary sections. In curves or gradients any deviations whatever may be made, if the sanction of the Board of Trade be obtained for them.

CLAUSE No. 15 prescribes that the *centre line* of railway shall not deviate from the line marked on the Parliamentary plans to a greater extent on either side than—

(*a*) in open country, 100 yards.
(*b*) in land continuously built upon, 10 yards, and
(*c*) nowhere beyond the "limit of deviation" as marked on the Parliamentary plans.

The engineer is bound by his "limit of deviation," as shown by the Parliamentary plans, when within the limits given by (*a*) and (*b*), and by this clause when those limits are exceeded. Provided that the adjoining lands into which the *works* would extend outside the limits, either as in (*a*) and (*b*), or in (*c*), have been referenced, the *centre line* may be deviated to the very *line* of limit.

CLAUSE No. 16, among other things, authorizes the company to divert any unnavigable stream, or any road within the referenced lands, for the more easy passing same over, by the side of, or under the railway.

As regards roads this is subject to Clause No. 56, *q. v.*

CLAUSE No. 17 requires the sanction of the Admiralty to any structure affecting tidal waters.*

CLAUSES Nos. 18 to 23 describe the necessary works and method of procedure, when the railway crosses water-pipes or gas-pipes.

CLAUSE No. 24 protects the engineer from having his work while staking out or surveying interfered with, by a penalty of £5 for every such offence.

It is of course to be presumed that in all such cases the engineer has a legal right to be on the ground, which he has when it is bought by the company, or, *as affects the contract survey*, when he has given the requisite notice of the intention to enter, as prescribed by 8 Vic., cap. 18, sec. 84. The engineer will do well not to act without precise instructions from the solicitor of the company.

* Subsequently altered by 25 & 26 Vic., c. 69, whereby the Marine Department of the Board of Trade is substituted for the Admiralty.

CLAUSE No. 25 requires the company, before proceeding to construct any portion of a railway in Ireland, to lodge with the Drainage Commissioners a copy of the plans and sections, and to receive from them a certified schedule of culverts and bridges necessary for any water flowing *across* the line of railway.

Drains under approaches to bridges, which are parallel or nearly so to the line of railway, do not come under this head, and are not noticed.

This lodgment with the Drainage Commissioners in Ireland is the only case in which the engineer is required to lodge the contract *sections*.

The next clauses affecting the engineering of the line are very important; they regulate the manner in which all crossings of roads shall be constructed.

CLAUSE No. 46 provides that no turnpike or public carriage road shall be crossed on the level, except specially authorized by the company's act.

The engineer must be cautious, when laying down his contract gradients, and making out his estimate, not to put down a road crossing as a "level crossing," merely because it appears on the Parliamentary plans that the road is "to be raised (or lowered) —— feet and crossed on the level." Roads are often, at first, proposed to be so crossed, but on the objection of the Board of Trade, many such crossings may be struck out of the Bill. The engineer must go entirely by the private Act, empowering the construction of the railway, and must make arrangements for every *public* road (not specially mentioned in it as *a level crossing*) to be carried over, or under, the railway, subject to the rules of the clauses 49, 50, 51, 52, at the same time allowing for

any infraction of these clauses that may be legalized by the special act and plans; *e.g.*, the Railways' Clauses Act requires an inclination of 1 in 20 for every public carriage road approach; but if the special Act sanctions an approach of 1 in 15 in a particular case, it may be constructed accordingly.

This clause enables the company, with consent of two justices, duly obtained, to make a level crossing on any highway not a *public* road.

CLAUSES Nos. 49, 50, 51, and 52 require—

First, that in the case of a turnpike road,*

(*a*) The width between the abutments, if the road be passed *under* the railway, and between the parapets, if the road be passed *over* the railway, shall in *no* case be less than 30 feet, and this width shall be increased up to a *limit* of 35 feet, if the road be wider than 30 feet.

(*b*) The arch shall be such as to admit of a rectangular box, 16 feet high and 12 feet wide, passing through it.

(*c*) The height of the springing of the arch over the ground shall be 12 feet at least.

(*d*) The inclination of the approaches to the bridge shall not be worse than 1 in 30, or than the mesne inclination of the existing road, if such be worse than 1 in 30.

* "The expression 'turnpike road' shall, when applied to any road "in Ireland, include any road upon which Her Majesty's mails are or "shall be carried in mail carriages; or such other roads as the Com- "missioners of Public Works in Ireland shall consider to require "arches of greater width or height than by this Act is required for "public carriage roads."—Interpretation clause at commencement of Act.

(*e*) The height of the parapets, if the bridge be over the railway, shall not be less than 4 feet, and the height of the fences on the approaches shall not be less than 3 feet.

Secondly, that in the case of a public carriage road,

(*a*) The width between the abutments, if the road be passéd *under* the railway, or between the parapets if the road be passed *over* the railway, shall in no case be less than 20 feet, and this width shall be increased up to a limit of 25 feet, if the road be wider than 20 feet.

(*b*) The arch shall be such as to admit of a rectangular box, 15 feet high and 10 feet wide, passing through it.

(*c*) The height of the springing of the arch over the the ground, shall be 12 feet at least.

(*d*) The inclination of the approaches shall not be worse than 1 in 20, or than the mesne inclination of the road, if such be worse than 1 in 20.

(*e*) The parapets and fences shall be as required above for turnpike roads.

Thirdly, in case of a private road,

(*a*) The width between the abutments, if the road be passed *under* the railway, or between the parapets, if the road be passed *over* the railway, shall be not less than 12 feet, no variation with the width of the road being allowed as in other cases.

(*b*) The arch must be such as to allow of a rectangular box, 14 feet high and 9 feet wide, passing through it.

(*c*) The height of the springing of the arch is not prescribed.

(*d*) The inclination of the approaches shall not be worse than 1 in 16, or than the mesne inclination of the road, if that be worse than 1 in 16.

(*e*) The parapets and fences shall be as required above for turnpike roads.

The width of the present road referred to above is the average available width of *carriage way*, within fifty yards on each side of the centre line.

The mesne inclination is to be taken for a distance of 250 yards from the point of crossing the same. That is, the inclination of an imaginary line, drawn from the point where the road is crossed to a point on the road at a distance of 250 yards.

As bridges for private roads almost invariably come under the head of accommodation works, the regulations of these clauses only apply where an accommodation bridge is settled on, either by agreement, or by a jury or arbitrator, without any dimensions or inclinations being specifically mentioned; in such a case the dimensions and inclinations laid down by the Act can be enforced. For this reason, the engineer, when settling accommodation bridges by agreement, or when appearing on behalf of the company before a jury or arbitrator, should endeavour to have the dimensions and inclinations described, in writing, in the agreement or verdict or award, in every case when the bridge or approaches settled on are not in accordance with this Act.

Before availing himself of the powers of this Act, with regard to reducing the width of roads, the engineer must remember, that in case of the authorities, at any future time, widening the road to twenty-five feet and thirty-five feet respectively, the company can be compelled to widen the bridge. In the case of under bridges, the process of widening would be so troublesome and costly that they should be made to the full width at first. In the case of over bridges, the cost of such alteration would be

comparatively trifling, and the engineer is justified in availing himself of the reduction in width, in order to reduce the outlay.

No corresponding powers can be exercised against the company to compel them to improve the inclinations of *approaches*, if made at first in accordance with this Act.

When a bridge is under the railway, the minimum dimensions that can be employed for a stone or brick arch, in accordance with this Act, are given in the following table:—

	If Segmental.			If Semi-Elliptical.		
	Span.	Rise.	Height of Spring-ing.	Span.	Rise.	Height of Spring-ing.
Turnpike Road—widest. .	35	4.50	12	35	4.26	12
,, ,, —narrowest	30	4.70	12	30	4.36	12
Public Road—widest. . .	25	3.53	12	25	3.27	12
,, ,, —narrowest .	20	3.87	12	20	3.46	12
Private Road	12	3.73	12	12	3.02	12

CLAUSES Nos. 53, 54, and 55 require that, previous to any road being interfered with, a good temporary road shall be substituted, under a penalty of £20 per day.

CLAUSE No. 56 limits the duration of such temporary substitution to six months, in the case of a turnpike road, and twelve months, if the road be not a turnpike road; with extension, by permission of those in charge of the road.

This clause also requires that in case of the interference with a road by diversion (*not specially authorized by the Private Act*) the company shall be bound to restore the road to its former state or put a substituted road into a

"permanently substantial condition, equally convenient as "the former road, or as near thereto as circumstances will "allow." The question how far expense is to be included under "circumstances" is one on which the lawyers are not agreed.

FIELD WORK IN PREPARING CONTRACT PLANS AND SECTIONS.

It is not unusual for the survey on a large scale of the lands through which the line is to pass to be made by a surveyor, and not in the engineer's office, and for the centre line to be *afterwards* staked out. The author's practice has been to have the staking-out done in the first instance, and the survey then made; all being done by his own assistants. The latter method of proceeding is here described:—

The engineer-in-chief having re-examined the line of railway, and finally determined on the precise course of the centre line, organizes a staff to execute the staking, survey, levelling, etc.

The circumstances which guide the engineer in making any deviations are the same as influenced him in the original selection of the route. He has now, however, a more minute knowledge of the ground, gained from examination during the Parliamentary work, and the reports of his assistants. He has also the advantage of the Parliamentary section, by reference to which he can determine on what alterations will be advantageous in reducing the cost of the works, whether by reducing the earthwork, the side-cutting, or the expense of the bridges.

One circumstance may render a deviation imperative, namely, the fact of the crossing of a road being proposed as a level crossing on the Parliamentary plans, but afterwards

struck out as such from the Bill. This would necessitate a bridge, and the centre line might require a deviation to make a bridge practicable.

The engineer-in-chief now divides the line into portions, as in Parliamentary work, to each of which he appoints two assistants, the one to stake out the centre line and make the contract section, and the other to make the contract survey.

The assistant who is appointed to stake out the line is first sent to the country, and when he has got a few days' start the surveyor may proceed to his work. The reason for their not starting together is, that as the surveyor's work should be based on the stakes which are put in by the first assistant, and as occasional delays will occur in the process of staking, the surveyor should not press too close on the engineer before him.

The steps necessary before the letting of the contract and the commencement of the works, may be stated as follows :—

In the field (1) Staking out.
" (2) Levelling.
" (3) Surveying.
" (4) Making map of farms.
In the office (1) Laying down the centre line on paper.
" (2) Plotting the section and cross-sections.
" (3) Plotting the survey.
" (4) Marking the land required for the railway, and calculating areas.
" (5) Plotting the line on farm map, and taking out severances.
" (6) Designing and making drawings of bridges, tunnels, culverts, etc.
" (7) Taking out the estimate.
" (8) Preparing plans for lodgment.

I propose to treat each of these processes *seriatim*, in the order in which they are placed.

STAKING OUT.

The chain used is either the 66 feet or 100 feet chain. The latter possesses many advantages over the former, especially in the convenience it affords in calculations of estimates and gradients. The only disadvantage the 100 feet chain labours under is, that it lacks whatever convenience is supposed to appertain to the fact of 10 square statute chains being equal to an acre.

The first thing to be done in the field is, to mark out the centre line of railway, putting in a stake at every chain length. The assistant-engineer is provided with an Ordnance sheet, or copy of Parliamentary plans, with the centre line, as ultimately decided on, marked with a fine red line; and his business is, from this guide to mark the line on the ground.

The centre line of railway, no matter how curved, may be considered as a series of *intersecting* straight lines joined by curves, and the process of staking out is based on this view. The engineer first prolongs all the straight lines on his map to their intersections, then transfers these lines to the ground, and lastly fills in the curves. It is a question of practice, or rather habit, with the engineer, whether he puts in *all* the straight lines (that is, pegs fixing their directions, though not the regular stakes) first, or follows up his work by putting in the joining curve as soon as he has marked in its two tangent lines. Some prefer one way, some the other. The only reason for the former is the fact of the engineer preferring to make his calculations connected with the curves in the house, in which case time is saved, by

simply ranging out the straight lines, and getting the data for the calculations, to be worked out in the evening at home. The author prefers the latter method, as very little practice enables the engineer to work out his calculations in the field, while it may happen, where a series of curves of contrary flexure occur, that one of the tangent lines, as first laid out, will make the curves overlap, and will require to be altered, perhaps by so doing involving the alteration of more in front of it, *if* they have been all marked out at once *before* this overlapping is ascertained.

A line is transferred from the map to the ground, by putting up five or six poles, or more according to its length, in well-defined points on it, such as the crossing of a fence at a measured distance from another fence. When these are erected, with flags on them, the engineer selects two to represent the line, and takes down the rest, putting in pegs at the two fixed on. The men employed generally are—one to carry and drive in pegs; one to carry the theodolite; two to chain; and a boy for running messages and for poles. An engineer can manage with less; but it is bad economy to save *cheap* labour at the expense of *dear* time.

In describing the process of staking, we will suppose that we are watching the engineer in the middle of his work; that he is staking out the straight line from A to B, (Plate 2;) that he has come up to the point A; and is now proceeding to mark out the next straight line, before putting in the curve. First remark that he stops some distance short of where he expects the first springing of the curve to be, because it would be a loss of time, and source of confusion, should he stake out the straight line beyond the springing point. All stakes so put in would have to be drawn, causing trouble, and, what is more important, loss of time.

He now proceeds to put up poles at c', a point determined

from the map, say by its distance from the intersection of fences; at c'', a point, say, in line of the gable of the house, and a certain distance from it; and at d'' and at d', both determined by fences. He now finds that these are nearly in a straight line, and puts in two pegs, say one at c'', and another *near* d'', such that their range will, in his judgment, most nearly represent the direction of the line on his map; *near* d'', because this peg should not be put on a fence, or in any other position rendering it difficult to plant a theodolite over it. Should he find that, from inaccuracy in the survey, or from the points not being well defined, the poles first put up are not in line, or nearly so, he must take an average, or ascertain the source of error.

His theodolite, with which he has been staking out the straight line up to A, is, we may suppose, somewhere on the line AB, set for that line, and with it he proceeds to put in two pegs, *a* and *b*. These pegs, observe, are placed so that the line CD passes between them, and should be only a few feet apart.

As a practical rule, to guard against loss of time, by driving these pegs in wrong places—*i. e.*, so that the line CD will not pass between them—it is well, when marking out CD, to leave poles at the points c''' and d''', roughly ranging them with the eye; with these poles to guide him, the leading chainman will have no difficulty in putting in the pegs at *a* and *b* properly.

The theodolite is now shifted to the peg near d'', and set to read the centre of the peg at c'', and, then, with it so set two more pegs are put in at *c* and *d*; these should be put in so that the line AB will pass between them.

In putting in *any* peg or stake, the leading chainman first holds up a pole at the spot, and shifts it, as directed by signals (not by *verbal* directions,) until the intersection of the wires

exactly bisects it; he then gets the peg or stake driven in, and finally holds up the pole again on the top of the peg, shifting as before; and when he has got the point of the pole exactly right, he, by pressure, accompanied by a twirling motion, makes a hole in the top of the peg; this mark, though not permanent, remains for some time, and enables him to hold up a pole again *exactly* in the right spot. Attention to small points like this conduces greatly to the accuracy of the work. All pegs or stakes that are intended to be permanent should be driven to within about one inch of the surface of the ground. A fine string is now stretched from *a* to *b*, and from *c* to *d*, and a peg driven in at the crossing. This peg will be referred to as the "intersection peg."

The theodolite is now set up over the intersection peg, and with zero of the vernier clamped to 360°, is directed to the point A, and all clamped.

Another point on the line AB should now be observed, that, by so checking, it may be certain that the point I is on the line AB: this check is essential in the ranging out of all straight lines.

The upper plate is now unclamped, and the telescope reversed, and directed to the point d'', *checking*, as before, on c''. The angle is now read off, and the difference between it and 180° is the "angle of intersection."

Additional accuracy is gained by *repeating* this angle.

The next step is to calculate from this angle, and the known radius of the curve, the length of the tangent, IC, or IB, of the secant IS, and of the curve BC. The line IS is not properly the secant, but is usually entered under that name in the engineer's note-book. Designating the angle bId, the observed one, by θ, and the radius by R, these calculations are made by the formulæ

$$BI = IC = R \tan \frac{\theta}{2}$$

$$Is = R \sec \frac{\theta}{2}.—R.$$

$$\text{Length of curve} = \frac{R \times \theta.}{57 \cdot 3}$$

θ, being expressed here in degrees, and decimals of a degree.

For example, suppose the angle θ to be $35° 34'$, and the radius of the curve to be 5 furlongs 3 chains, or 3498 feet. The calculations are:

$$\begin{array}{r} \log \tan 17° 47' = 9 \cdot 506159 \\ \log 3498 = 3 \cdot 543820 \\ \hline 3 \cdot 049979 \end{array}$$

which is the logarithm of 1121.96, which is, therefore, the length of each tangent, BI and ID,

$$\begin{array}{r} \log 3498 = 3 \cdot 543820 \\ \log \sec 17° 47' = 10.021264 \\ \hline 3 \cdot 565084 = \log 3673 \cdot 52 \end{array}$$

subtracting from this the radius, we find the length of the secant to be 175.52 feet.

$$\text{Length of curve} = \frac{35 \cdot 567 + 3498}{57 \cdot 3} = 2171.3 \text{ feet.*}$$

* If a table of lengths of circular arcs is at hand, the length of the curve is more readily obtained, by multiplying the number in the table corresponding to $35° 34'$ by the radius, thus: $3498 + \cdot 6207555 = 2171 \cdot 40$.

This length, though not so accurate as that given in the note, is quite sufficiently so for practical purposes.

With the theodolite still at the point I, and under its direction, a peg is put in at B, and another at C, at the proper distance. The engineer then bisects the angle BID with the theodolite, and directs a peg to be put in at a distance of $175\frac{1}{2}$ feet, that is at the point S.

These three pegs being in, the engineer returns to the work we found him at, and continues the staking of the straight line until he has driven the nearest regular chain length stake to B.

Staking out a straight line is such a simple matter as hardly to require description. The only things to be guarded against are, a mistake in direction owing to the instrument not being firmly clamped, and the stakes being driven in crooked. The former may be avoided by always reversing the instrument, and checking on the back stakes before shifting; and the latter by always taking a sight on the top of the stake, after it is driven.

The instrument should never (except in peculiar cases) be shifted to the last stake driven, but to a stake one or two back, so that by reversing a check may be obtained.

The engineer, when staking a straight line, is apt to forget the number of the stakes; as a preventative, a good plan is to give a charge to the leading chainman to drive a nail in the "centre" of every tenth stake, not necessarily in the middle of the stake, but on the point finally marked as the true "centre" of the line.

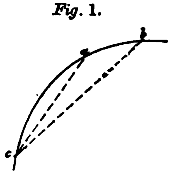
Suppose a 100 feet chain to be used, and that the stake nearest to B is No. 349, and the distance from it to B is 53 feet. The stake No. 350 will be *in the curve*, at a distance of 47 feet from the springing, and similarly the last regular stake in the curve will be at a certain distance from

the point C; these two distances are called the "first" and "second" "odd distances," respectively.

The best plan of putting in the stakes along the curve is that known as Professor Rankine's, who brought it into notice in a paper read by him at the Institution of Civil Engineers, on the 14th of March, 1843.*

This method depends on the fact that at any point on a circular curve the angle subtended by an arc of a fixed length is constantly the same, no matter in what part of the curve the arc or distance be taken, and the angle subtended by any other distance is proportional to that distance.

Fig. 1.



Hence if a theodolite be set up over *any* point *c* in the curve, directed to the point *a*, and then turned through the *constant* angle for 100 feet, the intersection of the wires will come on the point *b* at a distance of 100 feet from *a*.

If now, at the same time, one end of a chain be held at *a*, and a pole at the other end be moved about, still keeping the chain stretched, until the pole appears in the line of the telescope; then a stake put in at the point *b* will be the next stake, and will be *in the curve.*

Properly the distance from *a* to *b* should not be 100 feet, but the chord of an arc of 100 feet in length. In railway curves this error is of no account, as the radius is always so large, and in curves for sidings or tramways the error can be reduced by using short chains of 50 feet or 30 feet, or entirely got rid of by using a chain of the length computed for the chord of 100 feet of arc.

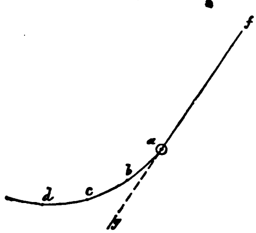
* There are other methods of laying out curves, some of which I will mention afterwards, and others that may be found in various works on this subject. Some of these methods have advantages under peculiar circumstances; but there is no method that can compete with Rankine's, where the country is close or uneven.

The angle subtended by any arc in a circle whose radius is R is equal to

$$\frac{\text{chord} \times 28{\cdot}648}{\text{radius}},$$

the result being in degrees and decimals of a degree.

Fig. 2.



The process, then, of putting in the stakes of a curve is this:—The engineer puts up his theodolite at *a*, sets it for the line *a g*, and turning it through the angle subtended by the length *a b*,* puts in the stake *b*. He then stretches out the whole chain, turns the instrument through the angle for a chain length, and puts in the stake *c*, and so on. The distance *a b* is what was called above the "first odd distance."

For convenience, tables have been compiled of the multiples of the angle for 100 feet for the usual radii, and also for all odd distances for the same radii. The angle for the odd distance can always be got by multiplying the angle for 100 feet by the odd distance, and dividing by 100.

If the engineer has tables so compiled, it is evidently an object for him to get the instrument to read the first stake *b*, with the vernier at 360°, so that all the succeeding readings shall be identically those tabulated, without any addition or subtraction. This is effected by setting the vernier *back* from 360° through the angle for the odd distance, before setting it to the tangent, and then the reading for the stake *b*, will be 360°. This is for a right hand curve, for a

* The angle between a tangent and a chord is equal to the angle subtended by that chord. Attention is drawn to this because confusion occasionally arises from what might be thought analogous, namely, that in setting out curves by offsets the first offset from the tangent is only *one-half* of the subsequent ones.

left hand curve the odd distance angle will be set *on*, and the after readings be read back.

Except in rare instances the whole curve cannot be seen from the springing, so that the instrument must almost always be shifted on. The stake to which it is shifted must be one on which the exact position of the point of the pole has been carefully marked. Having shifted the instrument, the best way of continuing the curve is to set it to one of the back stakes, making it read the angle belonging to that stake, and then the vernier is moved to the angle corresponding to the number of the next stake to be put in, and so on. Thus a check is kept on the number of the stakes.

Before starting with the staking out of a curve, the engineer should arrange the details of the curve in his note-book as follows:—

Radius, ...	3498
Angle of intersection, . .	144° 26′
Tangent, ...	1121·96
Secant, ...	175·52
Curve, ...	2171·3
Beginning at . . .	349,53*
Secant point at . . .	360,38·6
Ending at	371,24·3
First odd distance, . .	47
Second odd distance, . .	24.3
Angle for 100, . . .	49.1′
Angle for first odd distance, .	23.1′
,, second odd distance, .	11.9′

Having these details to refer to at once often saves time and confusion.

The use of the secant point is this: When the chaining comes to it, the line must pass *through* it, and not only

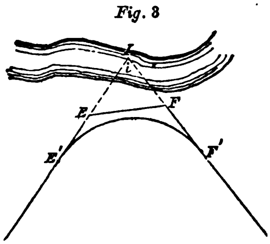
* That is at 53 feet beyond the 349th stake.

that, but it must pass through it at the exact *distance* pointed out by the position of the secant point in the note-book. If either of these checks fail, the engineer should go back at once, and search for his mistake. First, he should try over the angles and distances of his pegs, and if there is no mistake here, he should at once go to the intersection point, and try over his angles and tangent lengths. In the same way as the secant point acts as a check, the second springing also acts as a check. If the work passes these checks, and comes in right, both in angles and distances, the conclusion is *certain* that the curve is accurately put in, the chances against an error are incalculable. There is much more chance of an undiscovered error in staking out a straight line, owing to the absence of imperative checks.

Occasionally it happens that the intersection point occurs in a locality where it is impossible to put up an instrument, and sometimes where it is unapproachable at all.

The intersection may come, for instance, in the middle of a deep river.

Fig. 3



In this case the method of procedure is to put in pegs E and F at any two convenient points on the straight lines, the line EF is then to be chained, and at E and F the intersecting angles E′EF and EFF′ are observed. The sum of these two angles, minus 180°, is equal to the true "*angle of intersection.*" The lengths of EI and FI are next calculated :—

$$\mathrm{EI} = \frac{\mathrm{EF} \sin \mathrm{EFF'}}{\sin i}$$

$$\mathrm{FI} = \frac{\mathrm{EF} \sin \mathrm{FEE'}}{\sin i}$$

These lengths, and the length of the tangents, having been calculated, the differences between them and the *tangents* are laid off from E and F, respectively, and the springings put in, and the curve staked as described before.

In this case we are deprived of the advantage of the secant point, which, however, it must be remembered, is merely a check on errors to save time, and not essential.

Professor Rankine, in a paper read before the Civil and Mechanical Engineers' Society, December 6, 1860, gives, besides other interesting problems, a method of ascertaining an additional point in the curve, which will serve the object of the secant point in the ordinary case. The paper referred to is given in *The Engineer* of January 4, 1861.

Fig. 4.

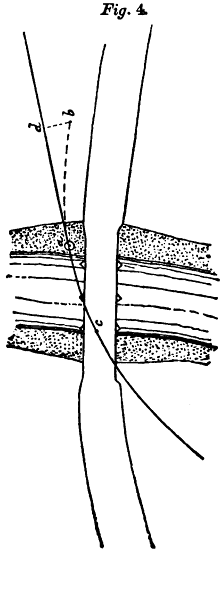


Figure 4 shows another peculiar case, where the springing, *a*, is situated on low land close beside a high bridge. The curve cannot be put in in the ordinary way, but the difficulty may often be got over by staking backwards a continuation of the curve until a point, *b*, is reached from which the curve at *c* is visible.

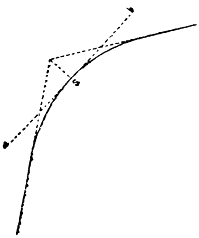
If *a* be so situated that the curve cannot be staked even backwards, then a point *b* may be got by taking any length on the tangent, and laying off the offset *bd at right angles.*

$$bd = R - \sqrt{R^2 - (ad)^2}$$

All that is wanted is a point *b in the curve:* its *position* in

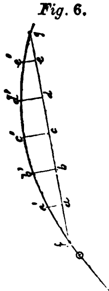
the curve is of no importance, so that the point *d* may be selected to suit the ground.

Fig. 5.



It may happen that *both* springings come on places where it is impossible to erect the theodolite. In this case the secant point *s* must be put in very carefully, and the instrument erected over it, and the curve staked out backwards and forwards from it, taking as tangent a line *ab* at right angles to the secant line.

Fig. 6.



Again, it may often be found impossible to bring a curve continuously round a precipitous face of a hill. In this case a straight line should be laid off from some point in the curve, so as to pass over accessible ground, and form a chord to the curve. This straight line should be carefully ranged and chained, and the points *a*, *b*, *c*, etc., marked, so that rectangular offsets will pass through the stakes in their proper position of a chain apart.

The distances *fa*, *fb*, etc., should be carefully calculated, they are to be got from the following formula :—

$$fa = 2\mathrm{R} \sin \left\{\frac{fa' \times 180^\circ}{2\pi\mathrm{R}}\right\} \cos \left\{\frac{ga' \times 180^\circ}{2\pi\mathrm{R}}\right\}$$

The distances *fa*, *fb*, etc., having been calculated, the engineer puts in pegs at *a*, *b*, *c*, etc., and afterwards goes over the line and sets off accurately at right angles the offsets *aa*′, *bb*′, etc., which are thus got—

$$aa' = 2\mathrm{R} \sin \left\{\frac{fa \times 180^\circ}{2\pi\mathrm{R}}\right\} \sin \left\{\frac{ga' \times 180^\circ}{2\pi\mathrm{R}}\right\}$$

These offsets, if small, may be got to a very close approximation, by a rule that does not require tables,

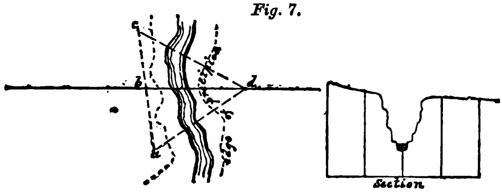
$$aa' = \frac{fa \times ag}{2R}$$

or, if the offset be large, and perfect accuracy required—

$$aa' = \sqrt{fa.ag + R^2 - \frac{fg^2}{4}} - \sqrt{R^2 - \frac{fg^2}{4}}$$

In staking out a straight line, the engineer may come on a steep ravine, with precipitous sides, for instance, 80 feet deep and 700 feet wide. In this case, it may be useful to determine a point on the centre line at the opposite side of the ravine by triangulating from a line on one side. The diagram shows, by the dotted lines, the operation necessary.

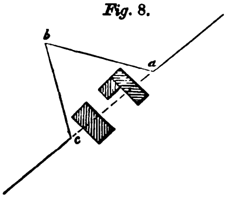
Fig. 7.



The line *abc* is to be chained, and the angles at *a*, *b*, and *c* observed, from which the distance *bd* is calculated. In the direct work, then, this serves as a check on the chaining up and down the ravine.

Again, the engineer may come on a wood, which he cannot under special circumstances, cut a way through, or houses of which possession cannot be immediately obtained. In this case, when he comes to a point *a* near the obstacle, he lays off a line *ab*, and measuring the angles at *a* and *b*,

Fig. 8.



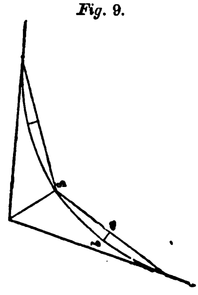
calculates the length of *b c*, and starts again at *c* with the calculated angle *b c a*. If this operation be repeated at the opposite side of the obstacle, or a tie-check be introduced, great accuracy can be obtained, and time saved.

The stakes having been all put in, the engineer next puts down the centre line on paper for the use of the surveyor, going through the same process in laying down the curves that he has used in the field.

The whole of the centre line, except on very short railways, cannot be continuously laid down on the one roll of paper, without making the roll inconveniently wide. It is, however, useful to get as great a length as possible of the centre line on the roll without a break. The easiest way to do this is to cut a piece of tracing paper to the dimensions of the roll, reduced in the proportion of the scale about to be used, and that of the map used in the field, and by shifting it about on the map, get the best position for the centre line, and then transfer that position to the large roll.

The tangent lines are then laid down, the springings marked, and the curve ruled in. The best way of laying off the intersection angles is to mark off on one tangent a measured distance, calculate the length of the tangent of the angle of intersection to that radius, and lay off that distance at right angles to the tangent; this is far preferable to the use of even the best protractor.

Fig. 9.



Having marked the second springing, the centre line is then ruled in with the proper curve.

Should the curve not be long enough to stretch from one springing to the other, the secant point must be plotted; and, should this not be sufficient, additional points must be got as follows :

The secant point having been laid

off, a line is drawn from it to each springing, and at the middle point of each of these lines, the distance *a b* is laid off. If no wooden or metal curve be available cut to the exact radius, a number of points may be plotted as above, by subdividing the arcs, and the curve then ruled in with the nearest curve.

The odd distances are then marked off from each end, and the position of the intermediate stakes marked on the plan. Owing to the difficulty of repeating distances accurately along a curve, the latter process requires some care, and should be done with a spring compass, which can be adjusted to make the pegs come in right, and keep them equidistant.

Great exactness is necessary in laying down the centre line and in marking the position of the stakes, as the plotting of the survey depends on their accuracy, both in position and distance.

Finally, the engineer who has staked out the line, makes out a list of the curves and their details, for the use of the engineer who is appointed resident on the works.

LEVELLING.

When he has finished the staking out of the line, and laid down the centre line for the surveyor, the assistant proceeds to level for the contract section.

Starting from a bench-mark at one end, he proceeds along the line, taking levels on the top of each stake, and also at each alteration in the ground level between them, which he thinks amounts to one foot or more, noting in his book the measured distances at which such observations are taken.

He should also note the exact distance at which the

centre of every fence crosses the centre line, and also, either by a sight, or by measurement, the height of each fence and depth of each gripe. The section thus becomes a check on the survey.

The importance of the fences being shown on the section at the proper distances, is greater than may appear at first, as when the works are being carried on, the only thing the managers or engineers of the contractors have to guide them is a copy of the section; hence a fence being shown at, or next to, the wrong stake may lead to confusion or mistakes.

While levelling, the engineer should watch carefully that no stake is skipped. The system of staking-out described above insures against a mistake being made in the number of stakes on the *curved* portion of the line; but no check exists on the accuracy of the number of stakes put in on the straight portions, except what will probably, but not necessarily, be furnished by the survey.

When he meets with any stream, the engineer should be very particular in noting the width and depth, the way in which it flows, and the average rate of fall. He should also measure the water-way of the nearest culvert or bridge over it on the down-stream side of the railway.

Having levelled over the entire of this section, the engineer proceeds to check his levels. As a general rule, it is better to check back on every stake. This takes but little more time than if he merely took the longest checks, and if any difference does occur, at once points out the exact spot where the error is. Another reason for checking on every stake is, that without it no check at all exists on the levels of those stakes that are points of intermediate sights when first levelled.

If the engineer has a middle district to level, he cannot

fill up the column of reduced levels until the level of some bench-mark common to them both has been given to him by the engineer on the district before him; but he can reduce his book to a datum of his own in a column on the far side of the right-hand page, for the convenience in comparing the original with the check levels.

Plate 3 shows part of a contract section, with a page of the level-book used in the author's office.

Check-levels should not show a greater discrepancy than one-tenth of a foot per mile.

Every change of the position of the instrument in levelling should be made with the staff on a stake-head or bench-mark. In windy weather, if reading high, the staffman should be taught to slowly wave the staff backwards and forwards in a line with the instrument, when the engineer can easily catch the true, *i. e.* lowest, reading.

Having completed the levelling of the longitudinal section, the engineer then proceeds with the road-sections and cross-sections.

The road-sections should be so taken as to show the surface line of the present road, and also, if the road be proposed to be diverted in any way, the surface along the proposed altered route. In either case, if the ground on either side be uneven, cross-sections must be made.

Occasionally, particularly in the neighbourhood of bogs, roads will be met with that stand at a pretty uniform height over the general surface of the ground: when making a road-section in such a case, a reading at each distance should be taken on the side as well as on the surface of the road, and the general surface of the ground at each side shown on the road-section, when plotted, by a dotted line.

As the road-sections are generally made before the contract survey has been plotted, the engineer engaged in

making the section is often at a loss to know what is to be done with a road, whether it is to be diverted or not, and what course the diversion will take. In case he is in doubt as to this, he should make a series of sections at short intervals parallel to the centre line, from which a true section can be produced in the office along the deviated course when settled upon.

The engineer will find it useful to have with him, when making road sections, a copy of the Parlimentary section, to enable him to form some opinion, making allowance for alterations in the course of the centre line, of the length of section required on each side of the centre line. He should note particularly if any substitution of a bridge for a level crossing has been made in the Act, as the section will require, in that case, to be much longer. Road-sections need not be either reduced or plotted to any particular datum; each may have a datum of its own; but each section must include a reference to some bench-mark by which the height of formation level may be be plotted on the road-section.

After (or, if he prefer it, before) making the road-sections, the engineer should make cross-sections at every stake, where the ground is sloping. In the open country these cross-sections should be made when the ground slopes with a greater inclination than 1 in 10, or is to any extent irregular; but in suburban districts greater exactness and more frequent cross-sections are necessary. Beside being taken at each *stake* where it is advisable to do so, intermediate cross-sections should be taken where necessary. These cross-sections are very important, as on them depends not only the quantity of earthwork, but also the width of ground taken. A more annoying thing can hardly occur to a resident engineer than to find that too little land has been taken, necessitating expensive extra works, or the purchase of more land at an exorbitant rate.

PLOTTING THE SECTION.

The engineer who was charged with the staking-out and levelling, now comes up to the office, and plots his sections and cross-sections, after which his special work is finished.

Longitudinal sections are plotted usually to a horizontal scale of 200 feet to one inch, or if the 66 feet chain be used three statute chains to one inch, and a verticle scale of 20 or 30 feet to one inch; the latter is in the author's opinion preferable, as it is amply large for showing an alteration in level of a few inches, and its employment on a long section often saves breaks, or alterations of datum, necessary to keep the section within a convenient height. The horizontal scale of the section should be always the same as the scale of the plan.

The engineer who has levelled the division adjoining the reference point for the parliamentary datum, under the directions from the engineer-in-chief, fixes the datum line, and ascertains exactly the difference between it and the parliamentary datum. When he has then reduced his book, he communicates the reduced height of his last stake, which should be common to them both, to the next engineer, who in his turn hands on the datum to the next. If the books have been reduced already, as suggested above, the datum can be communicated to all the men engaged in a few minutes.

The first care of the engineer in plotting the section is to obtain a perfectly straight datum line, which is not such an easy thing as may be at first thought, as it may be sometimes 30 feet in length on one roll of paper. It is very important that it should be truly straight, as otherwise the heights of cuttings and embankments, as shown by the distance of the gradient from the surface and that calculated

at each chain length, will be found not to correspond,—to the loss of confidence in the accuracy of the work.

Having joined a sufficient number of sheets of paper for the length of his section, he stretches the roll out on a long table, and marks points for the datum line. This is most correctly done by stretching a thin black silk thread from one end to the other, over that part of the paper where he wishes the datum line to be drawn, taking care to keep it when stretched clear of the paper, and then marking points along it at such distances as he can join with a true straight edge. The datum is then ruled in with Indian ink.

The next thing is to mark along this line the position of every stake, and draw rectangular ordinates with a fine pointed pencil, and then number every fifth stake, counting from the commencement of the line.

The engineer, for his own convenience and that of the surveyor, must in the first place number the stakes of his division of the line independently, and without regard to the divisions before him; but when the section is being finished off, the numbers must count from the commencement of the railway, or of a division of the railway, if it be proposed to divide it into separate contracts. He should also put in his field book, opposite each stake, the number that it bears on the section when finished.

Besides the ordinates at every chain, he should draw pencil lines for ordinates, at the distance of every observation in his levelling book.

Having plotted all the heights on these ordinates, he joins the points, taking care to put in all fences, drains, and walls, as shown by the notes he has made in the right-hand pages of his book.

The ordinates at every *chain length* are then ruled in with Indian ink, from the datum line to the surface of the ground,

and the reduced heights of each stake marked on the left-hand side of each ordinate near the datum line.

It will occasionally occur that in staking-out, the stakes come in places which do not truly represent the surface of the ground, as in the tops of fences, in haystacks, and sometimes in the roofs of houses. In such cases, two reduced levels should be given if possible, one of the stake itself and another of the surface of the ground. If, as often happens, the line runs for a considerable distance along the top of a wide fence, the section of this fence should be shown by a dotted line, and the true surface of the ground by a hard line.

The next thing is to write the words, "farm road," "public road," "river," "stream," "mill race," "avenue," &c., as each may occur.

The section is now ready for gradients, which cannot be well put on before the road-sections, cross-sections, and survey are plotted, as each of these must be taken into consideration by the engineer when fixing the gradients. Borings must also be made in order to ascertain the nature of the ground; these borings must be made at such distances and places as are directed by the engineer-in-chief.

The parliamentary gradients should now be marked on in pencil, as a guide to the working gradients, or rather in order to show the limits to which the working gradients may be deviated from them either in position or inclination.

As a general rule, the gradients should be laid down so as to give the least amount of work, at the same time, of course, not exceeding what the engineer-in-chief considers should be the ruling gradient, nor exceeding the limits laid down by the Railways' Clauses Act.

What was mentioned in Part I., page 19, about the intro-

duction of tunnels applies equally in the case of contract sections.

In cases where gradients causing heavy cuttings, without corresponding embankments, are unavoidable, dwarf walls are often introduced with economy, but only in cases where the cutting is in clay, and to be run to spoil.

Rivers, streams, accommodation works, and, above all, turnpike and public carriage roads, must be considered when marking the gradients, the efficient drainage of the latter, if under the railway, being a matter of primary importance.

If the country be uneven, the cross-sections will materially influence the quantities of cutting and embankment, and consequently should be plotted before the gradients are finally decided on.

Cross-sections are always plotted on a natural scale, that is the vertical and horizontal scales are the same, usually 20 feet or 30 feet to one inch. The height of cutting or embankment is then taken from the longitudinal section, and a line drawn showing formation level *for a double line*, and the slopes drawn in. From the edge of each slope is then set off a particular distance, *measured horizontally*, depending on the kind of fence to be used, and a mark made to show the boundary of the land required to be purchased.

Though the line is intended to be a single line, land is nearly always taken for a double line.

Also the width of formation level for the single line, on the side on which it is intended to be made, should be marked on the cross-sections, and the slopes drawn, and also a line marking the separation between rock and clay, if rock be shown by the borings, in order that the correct quantities of earthwork may be ascertained.

The road sections should also be plotted before the gradients are fixed: they are usually drawn to a scale of 20

feet to one inch vertically, and 100 feet to one inch horizontally.

Wherever stations occur, a horizontal portion, if possible, should be provided of, at the least, 700 feet, but the longer the better. *Ceteris paribus*, the best section for a station ground shows an average of four feet of *cutting*.

A sharp gradient falling *towards* a station should if possible be avoided, but it is not by any means objectionable if falling *from* the station, If a station *must* be put in the middle of a gradient, the inclination of part of the gradient must be increased, and the increase should always be made on that portion of the gradient that falls *from* the station.

The gradients having been marked, the next thing is to mark in figures at each chain length the height of formation level at that point, and also the difference between the height of formation level and the level of the stake or ground. Three rows of numbers have thus to be put on the section, one denoting the reduced level of each of the stakes, another of the formation level at each chain length, and the third, the difference of the two; the last-mentioned showing the height of embankment or cutting required at each place. These three rows may be put at the foot near the datum line, or the two former below, and the latter on or near the line representing formation level.

The copy of the section furnished to the contractor has only one row of figures, that of cuttings and embankments.

The heights of formation level, and indeed the other heights, are never given to more than two decimals of a foot; but when marking the reduced heights of formation level, the engineer should make on a separate paper a list of the heights, from one change of gradient to the next, to four decimals, and then enter on his section the two decimals most nearly corresponding.

The exact position of each springing of a curve should be marked on the datum line by a point, with a small circle round it, and a number denoting the distance of the springing peg from the preceding chain length. The radius of the curve and the words "curve begins," or "curve ends," should be written above the section, vertically over each springing.

The rates of inclination of each gradient, and the height of every change of gradient should be marked.

The distance from the commencement should be marked below the datum line every quarter of a mile.

As soon as the borings have been made, they should be marked on the section, with notes as to the nature of the ground.

SURVEY.*

The survey of lands for railway purposes is conducted in the same way as ordinary surveys, but possesses some special features.

In ordinary surveying, whether with the chain alone or with the aid of instruments, the process may be generally defined as consisting in the laying down of main lines, the construction on them of triangles upon triangles, and finally the filling in of the details.

Railway surveying is never so complex. The surveyor or assistant making the survey, coming as he does after the assistant who has been staking out, is thereby supplied with an accurately ranged and measured base line on which to found his work.

* The method of surveying here described is that generally in use when engineers have the survey done by their own assistants.

There are two forms of note-books used in surveying, one a large square book in which the whole work is sketched, showing the working lines, offsets, and fences, and the other, a long thin book, opening at the end, with columns ruled in each page.

The method by sketch-book requires no explanation : it requires a great deal of practice to keep the book neatly and distinctly.

In the other method, each page is ruled, as shown in Plate 5, and contains the distances and offsets measured along any one line of the survey; the position of that particular line being fixed by the description of the beginning and ending of the line.

The space between the red lines must be considered as imaginary, and the page must be looked on as if cut in two down the middle, and the halves separated by the width of the middle column.

If the engineer adopts the latter of the two methods of surveying, it will conduce greatly to clearness and speed in plotting to adopt the following plan.

One end of the book should be kept for the survey of the staked line, showing at the same time the general plan of chain lines adopted, and the method, whether tie-lines or angles, by which each point is fixed, designating the points by distinctive letters or figures. At the other end of the book, the chain lines themselves are entered, and distinguished by the description at the commencement of each, as, for instance, A to B, E to stake 184, 186 of AB to 230 CD, etc.

Plate 5 shows a page from each end of a book kept in this way. All pages should be numbered from both ends, and only one side of a page used.

The engineer must be guided by experience in laying

out a system of chain lines that will give him the survey with the least amount of labour, and consequently in the least time. He must decide on these lines from the Ordnance map or Parliamentary plan.

A point may be determined by two lines, one line and an angle, or two angles, but should never be left without a check, either a tie-line or a check-angle.

Offsets may be taken with a tape, but should not exceed 100 feet, except in rare instances, and then should be laid off with an optical square.

The engineer must be most particular about fences, houses, and roads within a distance of one hundred feet of the centre line; the parts of the survey further away do not require such accuracy, except in the case of roads which cross the railway.

As a general rule, the survey should extend to four hundred feet on each side of the centre line, and the fields to that extent should be closed. The fences are to be shown by single lines on the plan, and the position of that line is determined by the custom of the place. For instance, in some places, the boundary, which is represented by the line, is always in the centre of the mound of the fence; in others it is on the outside of the gripe.

The engineer should consult Williams' *Geodesy* for information about surveying in general. He will find there also most of the difficult cases that arise, and methods of surmounting them.

When the surveyor or assistant engineer comes to plot the survey, he gets the paper for it from the engineer who had staked out the line, with the centre line laid down, and each chain length, as well as springings, marked.

The centre line should be marked in Indian ink, which stands the rubbing which the plan must undergo much

better than blue or red ink, both of which are sometimes used.

After having plotted the survey, the engineer inserts the townland, parish, and county names, and their respective boundaries, usually in the same characters as they are distinguished by on the Ordnance map.

The next step is to put on the reference numbers; these should *exactly* correspond with the ones on the parliamentary plans.

Occasionally it will be found, that the contract plans differ from the parliamentary plans, owing to changes that have been effected in the lands between the times of the two surveys; fences may have been thrown down and two fields thrown into one, or new fences made and new enclosures formed. In the former case it is better to put both numbers on the contract plans, putting each number in about the same position as it occupied on the parliamentary plan, and in the latter case new numbers may be inserted, such as 17*a*, 17*b*, etc., care being taken that these do not occur anywhere else on the *parliamentary* plans in the same townland or parish.*

The plan is now ready to have the land required for the railway marked on it. For this purpose the engineer makes out a table of side-widths, showing opposite each chain

* This is the usual practice, but there is great doubt of its being right. Some are of opinion that *in no case* must the numbers on the plans for lodgment, for the purpose of making use of compulsory power of purchase, (for which the plans under discussion are used,) differ from the numbers on the parliamentary plans. To carry out this view, the parliamentary plan number must alone be used, and some way of obviating the difficulty devised for the schedules. The author now believes this latter plan to be right, but as it is rather a legal than an engineering point, recommends the engineer to get instructions from the Company's solicitor.

length the width of land required on each side of the line. This is called the table of side-widths.

Where the land is level, the side-widths are got by adding to the height of cutting or embankment, multiplied by the ratio of slopes, a constant which is one-half the width of formation level, added to the width of land necessary for fencing.

Where the land is sidelong, the side-widths should be taken from the cross-sections, measuring *horizontally*, and care taken that the widths, if different, are plotted on the proper sides of the centre line; it has happened in the author's experience, that the greater width of land required by the nature of the sloping or irregular ground has been taken on the wrong side of the centre line, leading to great trouble and confusion when the works came to be carried out.

If the section be very rough, side-widths should be also plotted, if required, at intermediate points.

When the side-widths are marked off on the plan, they should be all connected by a fine pencil line, and *checked*. If any roads are to be deviated, the land required for them, or for approaches to bridges, should next be marked, and then the boundary of the land required to be purchased marked with a fine red line, and the land coloured red.

The number of every fifth chain length should next be marked, and the acreage ascertained of all lands required to be purchased. Where other measure than statute is locally in use, it is convenient to put both on the plan. See Plate 3.

The acreages that have to be calculated are always small, rarely exceeding two acres, so that by bearing in mind the number of square feet in one acre, 43,560; in one rood, 10,890; and in one perch, 272¼, the engineer will find that the calculation will be effected as easily as if the divi-

sions on the scale represented links. However, if he should prefer working in links, he can do so by getting a corresponding scale to measure with. Thus, if the plan be made on a scale of 200 feet to one inch, a scale of 30.303 divisions to an inch will give the measurements in links. When all the measurements of works made by the engineer are in feet, or multiples of feet, the advantages of the 100-ft. chain are so great as to completely overbalance the slight convenience of having the plan plotted to links.

Every field, stream, private road, house, or enclosure of any kind, should have a separate acreage.

Public roads are usually measured into the adjoining lands, half to each side.

Finally, the plan and section are sent to the lithographer, and lithographed in sheets, each containing fifty chain-lengths of both plan and section.

DRAWINGS.

Preparatory to taking out the estimate, drawings must be prepared of all public road or turnpike road bridges over or under the line, of all river bridges, of culverts, of cross-sections of railway in clay and rock cuttings and embankments, cross-sections of road approaches, of level crossing gates for public roads and farm roads, and drawings of tunnels, if any.

Of course, the drawings for bridges never are made according to a fixed rule, the previous works of the engineer-in-chief, and alterations introduced by him, chiefly regulating the designs. The engineer-in-chief decides what bridges are to be stone or brick, and in what bridges it will be advisable to introduce cast or wrought-iron superstructures.

An explanation of the terms employed in bridge-building may be useful to beginners. Taking an over-bridge as in Plate 4:

"FOUNDATIONS" are the masonry laid below the ground and up to the level of the upper footing, or projection.

"ABUTMENTS" are the masonry from the foundations up to the beginning of the arch. When two arches abut against one another, the two abutments become combined into a "pier."

"SPRINGING" is the line at the top of each abutment where the arch meets it.

"SPRINGERS," or "springing course," is the top course of stone on the abutment, and becomes the

"IMPOST," when formed of projecting nicely-dressed stones, plain or moulded.

"ARCH-SHEETING" is the masonry forming the arch for a particular depth, as shown by the cross-section; the face stones of the arch-sheeting are called

"RINGPENS," which are the courses of face stones at each side of the arch.

"SOFFIT" is the concave surface of the arch.

"INTRADOS" is the lower line of the face of the arch, and

"EXTRADOS," the upper line of same.

"VOUSSOIR" is a term for the face of a single ringpen. Voussoirs are not shown on drawings, except of very elaborate and large bridges.

"WINGS" are the walls built to keep back the earth on each side of the bridge. Wings may be either curved or straight, and the latter may be either "straight back," or "splayed;" "straight back," when they are parallel to the rails, if an under-

bridge, or to the road, if an over-bridge; and "splayed" when running nearly at right angles to these directions. Wings are sometimes terminated by returns, or by

"NEWELS," which are built at the ends, with horizontal tops and covered with newel-caps.

"SPANDRIL" is the space between the arch-sheeting and the top of the bridge, bounded by the

"SPANDRIL WALLS," which may be external or internal.

"HAUNCHING" is the masonry that is put at the back, or over the "haunches," of the arch, and supports the internal spandril walls, if any.

"SPANDRIL ARCHES" are the arches covering the spaces between the internal spandril walls.

"STRINGCOURSE" is the course of dressed stone that caps the outside spandril wall, and supports the

"PARAPET," which is the side wall cf the road or railway.

"COPING" is the course of dressed work, which is always put on the top of each parapet, and also on the top of each wing.

"PILASTERS" are vertical projections, which occur in wings and parapets.

"PUDDLE" is a coat of stiff clay, usually put over the masonry of the arch, to prevent water draining into it.

"CAPS" and "BLOCKS" are dressed stones in positions indicated by their names.

"BLOCK-IN-COURSE" is coping of the nature of a continuous "block."

"COUNTERFORTS" are vertical projections at the back of each abutment, built to receive the thrust of the arch.

The considerations which regulate the employment of

stone, brick, or iron in the construction of bridges are two-fold—the abundance or scarcity, cost, etc. of the material itself, and the convenience afforded by the form in which it can be applied.

Though stone or brick bridges, *ceteris paribus*, should be adopted if possible, yet the consideration of height may so influence the question as to lead to the adoption of iron bridges, even where stone is plentiful. In the case of over-bridges, the reduction of the height may be of great importance as reducing the quantity of the embankment, or shortening the length of the approach. In under-bridges it may be of still greater importance, allowing a reduction in the height of an embankment, which should perhaps have to be made from side cutting. Iron bridges may also be adopted for another reason, on account of any insecurity in the foundations that would render some slight settlement in the abutments probable. An arch might be seriously damaged by a settlement that would in no way affect an iron superstructure.

When the general form of the bridge, and the angle at which it crosses the railway, if an over-bridge, or the road, if an under-bridge, have been determined on, the engineer proceeds with the drawing. Suppose, for instance, that he is engaged on an over-bridge, such as is shown on Plate 4, with splayed wings and a segmental stone arch.

The first lines to be drawn are the centre lines of both road and railway on the plan, and the formation level and surface of ground on the elevation. The "section through the abutment and arch *on the square*" should then be drawn, and also the general cross-section of the wings.

In designing a bridge, all the parts of the drawing must be carried on together, neither plan nor elevation can be finished by themselves, without having the sections drawn,

or as vividly impressed on the mind as if they were drawn.

In drawing the cross-section of the abutment, the dimension of the foundation courses will depend on the nature of the ground, but they generally are wider than the abutments, and terminate in a footing at one foot below formation level, projecting at least nine inches.

Even where no additional width of bearing surface is required, the footing is usually put, so as to afford a fair level surface on which to start the neat work.

The footings in over-bridges should be at least one foot below formation level, to enable the water tables, or side drains, of the railway to be carried continuously through the bridge. The projection of a footing depends on the material employed; every front stone in a footing course should be at least as much embedded in the work as it is exposed, else the footings lose their value, which is to spread the pressure: hence the projection mentioned above may be increased, or must be diminished, according to circumstances. If a greater width of foundation be thought necessary, it must be gained by increasing the number of the footings, and not the width of each.

The span and rise of a segmental bridge being given, the radius of the circle of which the arch is a segment, is found by the equation,

$$R = \frac{r^2 + s^2}{2r}$$

where R=radius, r the rise, and s the semi-span of the arch. In segmental arches of moderate span, the extrados is usually struck from the same centre as the intrados. The thicknesses of the arch and of the abutments have been the subjects of theoretical investigations, but *practically*

depend on previous examples. It is possible to determine the width of an abutment that will just keep the arch in equilibrium, but this has to be modified by a *coefficient of safety* (in itself very variable,) so that the value of the theoretical rule is practically lost.* The haunching is usually carried up at the back in a plumb line with the abutment, terminating at a point one foot or more below the level of the soffit of the crown of the arch, and raked from that in a line tangent to the extrados, to allow water to run freely off. Steps are sometimes introduced to lighten the haunching.

The counterforts are shown in section at the back of the abutment, and are usually plumb at the back. Sometimes they are raked off in a line with the haunching, and sometimes are stopped lower down. Their object is to help the abutment to withstand the thrust of the arch. There is no use in founding counterforts as low as the abutments when the bridge is in cutting, it is enough that they should have a good foundation for themselves. They may or may not have footings. The puddle is usually shown six inches deep, and should extend over the counterforts.

From this section the abutments and counterforts can be drawn on the plan, and projected to the elevation.

In the case of a skew bridge, the elevation of the arch is elliptical. If the arch be a semi-ellipse, the elevation will also be a semi-ellipse, but with a major-axis equal to the span on square, multiplied by the cosecant of the angle of skew. If the arch be a circular segment, then the elevation will be an elliptical segment, with major-axis as above.

The different methods of drawing ellipses will be found in any book on drawing.

* The author must not be taken as disparaging theoretical knowledge; *new* designs without it would be mere guess-work; he only means that in ordinary every-day practice previously executed works are the usual guide.

In the bridge under consideration, the next step is to draw lines at the distance back from the front of the abutment at which the wing is to be splayed, and then lines parallel to the centre line of road, indicating the intersection of the wing with the newel.

Before this last can be done the "section through the crown of arch, viewed on the square," must be drawn, and the elevation of the wing on the square plotted. The intersection of these four lines will then give the extreme points of the wings. If the wings be battered, and also stepped in the foundations, a point (*a*) must then be laid off at a distance equal to the batter due to the height of the end of the wing over the foundation of the abutment, and a pencil line drawn from it to *b*, the point at which the lower part of the wing joins the abutment. The distance from *b* to the corner of the abutment usually is at least one foot, sometimes more. If it be made very small, a practical difficulty in building is introduced, and, except great expense be incurred, bad cross-bonding into the abutment induced. The lines representing the footings of the different steps of the wing will be each parallel to the line *ab*, standing back from one another at a distance equal to the batter of the height of each step over the one below it. To get the top of the wing, the point *f* is laid back from *ab*, at a distance *on the square* equal to the batter of the highest part of the wing.

In the design in Plate 4, it will be seen that the parapets are curved, and consequently the point *e* is lower than the crown of the extrados; the curve is so regulated as to have, at the points immediately over where the wings join the parapets, tangents at an inclination of 1 in 20, (this bridge being for a public road,) and consequently the radius of this curve is equal, *quam proxime*, to $ce \times 20$, and in

other cases equal to *ce* multiplied by the inclination of the approaches.

With this curve in the parapets, the point *e* will be lower than the crown of the extrados by a height

$$\text{equal to } \frac{ce}{2 \times \text{inclination}}, \text{ in this case } \frac{ce}{40}.^{*}$$

The point *f* then having been got, the plan of the top of wing immediately under the coping is drawn in. In this bridge there is a "return" of the parapet, and the portion *fg* represents a *horizontal* surface, consequently the line *fg* is parallel to *ab*. The point *g* is then joined to the point *d*, and the back of the wing drawn in parallel to it, with the plan of the steps of the wing, as shown by the section of same.

The width, *on the square*, between the abutments of an *over*-bridge, or between the parapets of an *under*-bridge is regulated by the requirements of the Board of Trade, as mentioned hereafter. Four feet clear being required on each side of the railway, and six feet clear between the two roads, if the bridge be intended for a double line.

The gauge in England is 4 feet 8½ in., and in Ireland 5 ft. 3 in. clear between rails.†

The width *on the square* between the abutments of an *under*-bridge or between the parapets of an *over*-bridge is regulated by the Railways' Clauses Act. (See pp. 33-35.)

The rest of the drawing of this bridge is so simple as to require no explanation.

* These values are only approximate, but quite near enough for practical purposes.

† These gauges are fixed by Act of Parliament, 9 & 10 Vic., cap. 57. Several private Acts have since been passed, having in each case a clause giving power to use a narrower gauge. No regulations as to clearance outside or between the lines of rails in such cases have yet been issued by the Board of Trade.

Curved parapets are not by any means universal: it is doubtful whether they are preferable to straight, and they are decidedly not so when carelessly executed; the rule is given as useful *when* they do occur.

When an under-bridge has inside spandril walls, they should be so spaced as to insure the rails being over the middle of two of them.

The colouring and printing put on a drawing are matters of taste, but as a general rule, neatness and *accuracy*, not ornament, should be aimed at.

On the *plan* of every bridge should be shown at least three views, one of the superstructure complete, one of the bridge, or part of it, with the parapets, string-course, coping of wings, and newel-caps removed, and a third of the foundations.

As a general rule, in the case of river bridges, the engineer should provide a water-way equal to that of the next bridge over the river *lower down;* but this rule is, of course, subject to circumstances, such, as the distance from the bridge being considerable, other streams joining the river between, etc.

The sizes of the culverts must be decided on similarly, the best guide being the size of the nearest culvert to the railway *down the stream.*

The portions of the masonry, or brickwork, which are represented *in section*, are usually coloured pink or blue. Masonry, *in elevation*, is not coloured on working drawings. Iron and timber are always coloured on a drawing; the for-

* Should there be no such culvert, the engineer must look to the catchment basin of the stream, and any information he can get as to the rainfall of the district. Except he has reason for not doing so, he should provide for, *at least*, a discharge equivalent to a rainfall of 1½ inches in twenty-four hours, one-third of which is to pass through the culvert in the same time,

mer blue, or rather a neutral tint, and the latter with burnt sienna. In drawings of iron bridges, the wrought-iron is usually represented by a much brighter tint than the cast-iron, though this is sometimes reversed, and the fact of any iron being *in section* is shown by lines drawn diagonally all over it. Timber in elevation is shown by plain sienna, and when *in section*, by the same crossed by diagonal lines of the same colour.

As many written dimensions should be shown on the drawing as would enable a mason to proceed with its construction, without reference to the scales, though the latter should never be omitted.

The *written* dimensions on the drawing should be always specified to be binding, in preference to those ascertained by scale, but are in their turn subject to any dimensions stated in the description of the bridge, embodied in the specification.

The theory and design of iron girders is too large a subject to be discussed to any extent in these pages; a few memoranda only are given, which may be found handy for reference. The reader is referred for information on the subject generally to the exhaustive treatise on the "Theory of Strains," by B. B. Stoney, a book which ought to be in every engineer's library.

Wrought-iron girders are the usual resource of the engineer when large spans are essential, or when it is an object to keep the level of the rails lower than would be possible with an arched bridge in passing over roads, rivers, or railways. They may be divided into three classes.

1. Under-girders, placed under the railway.
2. Side-girders, placed on each side of the railway which itself rests on cross-girders.
3. Sandwich-girders, in which *each* rail is placed in a sort of trough between two girders.

Under-girders are the simplest and most economical form of girder; their use instead of stone arches saves a good deal of headway, though not so much as is saved by a side-girder bridge. The greatest saving of headway *combined* with economy is afforded by the sandwich-girder, but its use is limited to small spans.

Under-girders for very small spans, such as 12 feet cattle passes, usually consist of a web of plate-iron ½ inch thick with an upper and lower flange of plate-iron secured to the web by an angle iron on each side. The angle-irons are usually 3¼ inches × 3¼ inches × ½ inch. The width of the flanges is never less than that of the two angle-irons added to the thickness of the web, and often extends over the angle-irons if additional sectional area in the flange be required. Rivets are usually placed 4 inches apart "centres," and for such girders they are ¾ inch in diameter.

When the span is a little larger, say 15 feet, it becomes economical to replace the plate-web by a single set of lattice bars, and afterwards, say at 20 feet span, by a double set of lattices constituting a "box-lattice" under-girder.

The width of the flange of a box-lattice girder, (excluding special viaduct works,) ranges from 1 foot 6 inches to 2 feet 6 inches.

On small spans the under-girders are placed directly under the rails, but in larger spans where the flange is wide it conduces to steadiness to separate the girders, which will then be cross-braced as far as possible consistent with still retaining the rail-seat fully over them.

Small plate under-girders with plate-webs may be let into cast-iron chairs, resting on bed-stones on the abutments, the gauge being kept true by transverse bolts through the girders.

Lattice under-girders are generally seated on cast-iron wall plates, which should have recesses cast to receive the

rivet heads, and which should be connected by tie bars to prevent shifting. It is a common but bad practice to countersink or hammer up the rivet heads under the end of a girder, so as to make it sit on a flat wall-plate.

Box-lattice under-girders over 40 feet are usually braced together, so that to a certain degree two girders form one beam.

The planking on top of under-girders should not be less than 4 inches thick.

Every rail on top of an under-girder should be fastened to it by four bolts and nuts passing through the rail and upper flange of the girder.

The edges of the planking on small spans may rest on a light rolled beam, or very light lattice-girder, surmounted by a light hand-rail for the protection of the plate-layers.

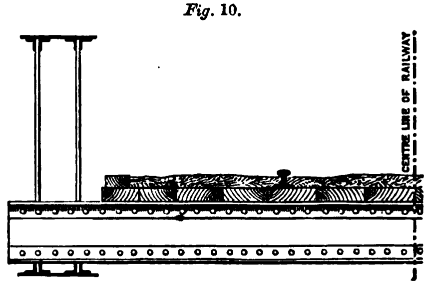
Side-girders with cross-girders to carry the rails are used where it is desirable, in the case of moderate spans to save more headway than can be done by under-girders.

They are sometimes constructed of a single plate-web with plate-flanges, but the box-plate or box-lattice side-girders are more usual.

The railway between side-girders may be supported in two ways :—

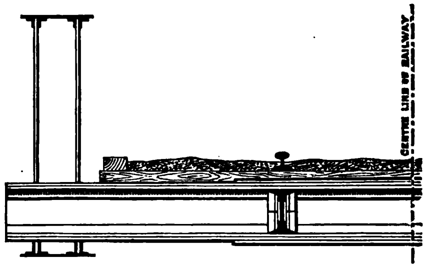
1. By single cross-girders placed 3 feet apart "centres."

Fig. 10.



2. By compound cross-girders of a stronger construction placed at greater intervals and carrying a subsidiary system of under-girders under each rail.

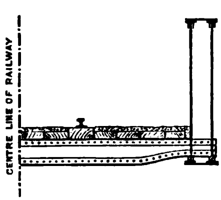
Fig. 11.



If the headway under the girder is of great importance the system of single cross-girders at the same distance apart as sleepers, (3 feet centres) must be adopted. Over these cross-girders and under the rails longitudinal sleepers of half balks may be laid, *but if so, no count can be taken of the available strength of them to distribute a passing load over more than one cross-girder.*

Simple cross-girders are usually formed of a plate-web ½ inch thick, with an upper and lower plate-flange secured by angle-irons to the web. An improvement was introduced by Mr. Anderson, in 1858, in the re-construction of the centre span of the Bray Viaduct on the Dublin, Wicklow, and Wexford Railway, by making cross-girders fish-bellied, by which the bottom of the cross-girder at its centre was made to be level with the bottom of the main-girders, and 4 inches headway, *at least*, saved, an improvement now universally adopted.

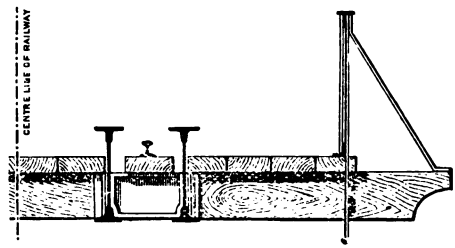
Fig. 12.



If the side-girders are plate or box-plate girders the cross-girders are usually riveted to them, the angle-irons being turned down for the purpose; but if the side-girders are box-lattice girders the cross-girders usually rest on cast-iron chairs fitted to the bottom flange, and sufficiently high to keep the ends of the cross-girders up off the angle-irons of the flange of the side-girder.

Sandwich-girders, also originated by Mr. Anderson,* are

Fig. 13.



an adaptation of the old cast-iron trough girders. They are applicable only to small spans, but up to spans of 35 feet combine the greatest headway with the greatest economy.

Sandwich-girders are formed by a pair of plate-web girders, placed on each side of the rail, which is bedded on a half-balk sleeper, resting on cast or wrought-iron chairs 3 feet apart, which should be *riveted* to each girder. Their application is limited, because the top of the girder cannot rise more than 2½ inches over the top of the rail. Light girders of either timber or iron are required on the outside to support the platform.

When the kind of girder to be used and its depth are

* Transactions of the Institution of Civil Engineers of Ireland, vol. viii., p. 48.

decided on, the next step is to ascertain the *area* of the lower flange, (in practice, the upper and lower flanges are made identical.)

If w be the weight in tons which the bridge has to carry, distributed evenly over its length, or such a weight as, distributed evenly, would cause a strain equal to the maximum the bridge is likely to incur,

w' be the dead weight of the bridge and platform,

l be the clear span in feet,

d be the depth of the girder in feet,

s be the maximum working strain which, as required by the Board of Trade, may be taken at 5 tons per square inch,

a be the area of the flange at the centre of the girder, by which is meant the available working area, deducting holes that have been punched for rivets, *and also* ⅛*in. on each side of each rivet hole*, for the deterioration of the surrounding iron by the process of punching,

Then the area of flange is given by the equation—

$$a = \frac{8 \times s \times d}{(w + w') \times l}$$

The girder being assumed to be of constant depth, the area of the flange, at any point distant x feet from one end, and y feet from the other, should be—

$$a' = \frac{4 \times a \times x \times y}{l^2}$$

In the case of very large spans, w may be taken as one half ton per lineal foot for *each rail* supported by the girder, exclusive of the dead weight of itself and platform, but for small spans, it becomes comparatively greater.

Mr. Stoney* gives the following table, assuming such traffic as would put 1⅓ tons per running foot on a span of 100 feet:—

Length of Bridge in feet.	Working Load in tons, per running foot of single line.
12	2.67
16	2.5
20	2.24
24	2.0
28	1.79
32	1.62
36	1.48

The dimensions of iron, as it is made, restrict the engineer in the application of theoretical refinements. In the first place, very short girders are always made much too strong, because it is not considered advisable to use iron of less than half-inch thickness.

Again, for ordinary work, the engineer is practically restricted to plates of a certain size and length, say 12 feet 2 feet 6 inches, and to variations in thicknesses of plates of not less than $\frac{1}{16}$th inch.

He must bear all this in mind in designing a girder.

Care must be taken that the *area* of the flange at the end of a plate which is nearer the middle of the bridge is sufficient; in which case it will, but unavoidably, be more than sufficient for the rest of that plate.

The junction of all plates must be secured by covering plates, by which the strength of the joint will be made up to that of the weaker of the two plates or sets of joining plates.

The number of rivets required on each side of the joint for a covering-plate should be at least that of the available working

* Theory of Strains, 2nd Edition, 1873, page 513.

area of the weaker plate divided by the cross-sectional area of a rivet.

The position of the rivets in covering-plates should be distinctly shown, no rivet being nearer to another than four inches, centres.

For lattice-girders of small spans up to 20 feet, the lattice-bars are usually made of $2\frac{1}{2}$in. × $\frac{1}{2}$in. bar-iron. A smaller scantling does not well stand riveting. For spans of from 25 to 35 feet, 3in. × $\frac{1}{2}$in. lattice-bars are used. Up to this, it would be an unusual refinement to go into the detail of varying the scantlings of the lattice-bars. In large bridges, however, it becomes a serious matter, and great attention must be paid to the dimensions and form of the lattice-bars, the proper shape being given to those exclusively in tension and compression respectively, and also to those which may be at one time in tension, at another in compression. The engineer must consult Mr. Stoney's work or others for this.

Cast-iron girders are now only used for carrying roads over the railway. For this purpose they are usually placed about five feet apart and tied together by wrought-iron tie rods. The road-way is then formed by brick arches thrown from girder to girder and covered with metalling.

The breaking weight in tons, evenly distributed, of a properly-proportioned cast-iron girder is equal to—

$$\frac{56 \times a \times d}{l} \text{ in tons,}$$

and from the requirements of the Board of Trade given in the appendix, we deduce—

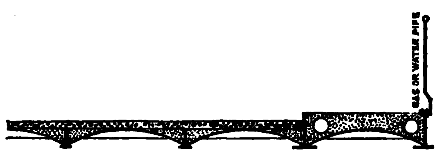
$$\frac{56 \times a \times d}{l} = 3w' + 6w,$$

the letters bearing the same meaning as before.

The working load on an over-bridge may be taken at 100 lbs. per square foot of roadway.*

It is occasionally essential to obtain a less distance between the surface of the road and the bottom of the girders than can be got with cast-iron girders and brick arches. For this, if there be two sets of rails, they are separated to pass under two single bridges, which may be each of a span of 8 feet added to the width of gauge. With such a small span a very shallow top may be made with rolled beams, placed about 5 feet apart, with bent wrought-iron plates between, all well tied together, and flushed with concrete level with the top of the beams. Over the concrete comes the usual road metalling. The outer-girders to carry the hand-rail may be cast-iron, as their depth is not limited.

Fig. 14.



The number of copies of each drawing required is four, one for the contract deed, one for the engineer's office, one for the resident engineer, and one for the contractor; the last two are usually made on tracing paper.

No drawing or tracing should ever be allowed to leave an office without the proper scales being shown on them.

* Stoney, p. 517.

SPECIFICATION.*

The following may be taken as a good form of specification :—

________________________*Railway*.

DIVISION No. ——

SPECIFICATION OF WORKS.

1.—EXTENT AND DESCRIPTION OF WORK.

The work included in this contract extends from the point marked by a stake, numbered on the plan, in the field numbered in the townland of and parish of to a point marked by a stake, numbered on plan, in the townland of and parish of the whole extent of which is miles, furlongs, yards (statute measure.) The commencement of the work is marked by a stake, numbered on the contract plan. The centre of the line is marked on the ground, through the whole length, by stakes driven into it at intervals of one hundred feet, corresponding with the numbers marked on the sections and plans. The work included in the contract will consist of the necessary excavations and embankments, formation of drains, cuts, and channels, building of bridges, culverts, walls, drains, erecting fences, gates, retaining walls, breast walls, forming and metalling road-ways, soiling and dressing slopes, ballasting and boxing, forming and metalling approaches to bridges, diverting roads, forming new ones, laying the permanent way, &c., &c., and every other

* The above form is that used by the author, taken, with slight alterations, from specifications of Mr. W. R. Le Fanu, M. Inst. C. E., and Sir J. Macneill.

work that may be necessary for the entire completion of the line, whether specially named herein or not, except providing the permanent sleepers, rails, fastenings, and chairs, which will be done by the company themselves. The work, when finished, and ready to receive the rails, is to be in every respect in strict conformity with the plans, drawings, longitudinal and other sections, signed by ________, engineer to the company, and numbered consecutively from to inclusive, that is to say, the widths of the cuttings and embankments, their slopes and dimensions, are to be in every instance in conformity with the said drawings and the written descriptions on each of them respectively, or as may be determined by the engineer-in-chief, or resident engineer, and the level of the bottom surface of the ballasting or formation level, is to agree with the levels and rates of inclination shown on the longitudinal section.

The contract is to include the providing of all materials, land for spoil and side cuttings, tools, implements, temporary rails, and sleepers, &c., the repairs of all county and private roads required by the Act of Parliament, labour of of every description, and the formation of all temporary roads that may be required for the carriage of materials, or for public or private use, while existing roads are interfered with, and all temporary fences that may be found necessary for the protection of the lands through which the works are made, or from which and through which materials are taken or carted, and for the working and rent of quarries, and all temporary or permanent damage done to lands through which the line passes, or which are adjacent thereto, or from, through, or on which materials have been taken or deposited ; and also the keeping of all the works in repair for one year after the line is opened for Public Traffic.

2.—TEMPORARY FENCES.

Before commencing the work on any part of the contract, if the permanent fences be not made, temporary fences are to be erected, to prevent cattle from trespassing on the adjacent lands; these fences may be of any description that will answer the purpose, but they must be sufficiently strong and durable to prevent injury during the progress of the works, and every precaution is to be taken by the contractor to prevent injury or annoyance to the proprietors or tenants of lands and houses along the line; and he is to be accountable and to pay all expenses and damages arising from trespass or otherwise during the progress of the works. Wherever the temporary fence is not deemed secure by the engineer-in-chief, or resident engineer, he has power to order such additional protection as he may think necessary, at the contractor's expense. Wherever it shall be pointed out by the resident engineer as necessary, temporary gates shall be erected and kept in order by the contractor. No claim to be made for the expense of such temporary gates.

3.—REMOVING SOIL.

The upper soil is to be removed from the ground to be occupied by the cuttings and embankments, in such quantities as will be sufficient to cover the slopes of all cuttings and embankments, whether of the line of railway, or the approaches of bridges, to a depth of six inches. If a proper quantity be not preserved from the line of railway, the contractor must find it elsewhere at his own expense; soil thus removed to be placed on each side of the line, out of reach of the works, and to be replaced on the slopes of cuttings and embankments when completed, or at such times as the resident engineer may point out and direct.

4.—EXCAVATIONS.

The extent of excavations is shown on the longitudinal and cross-sections, hereinbefore mentioned or referred to. They are to be cut to the depth of the formation line marked on the said cross and longitudinal sections, and to the slopes shown thereon; but the company's engineer reserves the power to make any alterations in said cross and longitudinal sections as the work proceeds, and the contractor is not to be paid for any excavation beyond said altered sections, nor be allowed to excavate more or less than may be therein shown. If the alterations exceed this contract, he will be paid extra, and if they require less excavation than this contract, he will be paid less, both as per schedule price. In general, the slopes will be one-and-a-half horizontal, to one perpendicular, through gravel and clay; but in case of rock cuttings, the slopes will be   to one; but in no case must the width of the excavation at the level of the formation line, mentioned above, be less than fifteen feet in rock cuttings, nor less than eighteen feet in ordinary clay and gravel, as shown in the said cross-sections, see drawing No.   except where otherwise specified on the section. And should it be found that the contractor has failed to take out any of the cuttings, whether rock or clay, to the full slopes, widths, and levels shown on the respective drawings, a deduction will be made for the quantity which he shall have omitted to take out, at the price per cube yard in the adjusted schedule. At the final settlement the contractor will be allowed for the full quantities of rock and clay mentioned in the schedule of quantities annexed to contract, deducting all omissions, as above referred to; and no claim will be allowed for any excess of cutting, whether rock or clay, except such as shall

have arisen from alteration of gradients ordered in writing by the engineer-in-chief. All the materials arising from the cuttings are to be applied in raising the embankments, when so required by the resident engineer; and, should they produce more than is necessary for this purpose, the residue is to be applied in giving a greater width to the embankments, in widening out the slopes, or otherwise to be disposed of by the contractor, (he paying for the ground, if any be required for spoil banks,) as may be pointed out by the resident engineer; such spoil banks in all cases to be made outside the boundary of the company's land, except specially allowed to the contrary in writing by the engineer. All the slopes are to be carefully levelled, trimmed, and dressed, and to be reported by the resident engineer to be in a fit and consolidated state before the soil is laid on, which is to be done to the depth of not less than six inches. All slips in the cuttings are to be made good by the contractor at his own expense, from time to time, until the work is taken off his hands, which will be done one year after the opening of the line for public traffic, should the engineer-in-chief consider that all the works have been executed according to contract.

5.—EMBANKMENTS.

The extent of embankments is shown on the aforesaid longitudinal and cross-sections. They are to be raised to the height of the formation line marked on the said sections, and to the width of not less than eighteen feet at that level. When completed and ready to receive the ballast, the slopes of all the embankments are to be one-and-a-half horizontal to one perpendicular, except where otherwise specified on the said section. See drawing, No. . If the stuff procured from the cuttings be not sufficient to make up the

embankments to the height marked on the sections, and to the proper slopes thereon specified, the necessary quantity must be taken from the cuttings by widening or flattening the slopes to a greater extent than specified for the excavations, or from side-cuttings, as pointed out by the resident engineer, without any additional expense to the company. The embankments are to be made up from time to time, as they subside, or the contractor may carry them to such a height above the specified levels, in the first instance, as will allow for the subsidence, if he thinks proper so to do; but in no case is the slope to be formed less than one-and-a-half to one, unless otherwise specified on the section. As the works proceed, this slope must be maintained and strictly adhered to. No additional quantity of stuff must be thrown over the sides to bring the slopes to the proper form; it must be done in the first operation and construction of the work. When the embankment is carried over bridges, arches, culverts, or drains, care must be taken to carry up the embankment in regular lifts, of such height as the resident engineer shall think necessary, on each side of such arch, bridge, or culvert, so as to prevent an unequal pressure on either side; and if it cannot be otherwise done, a stage must be erected across the arch, bridge, &c., to allow the earth to be carried to the opposite side, or it must be done by planks and barrows. In all cases where the embankment abuts against masonry, whether abutments, piers, or walls, it is to be well rammed to the height of the masonry, and to the width of ten feet from it, or more, as required by the nature of the work, to be decided by the resident engineer. When the slopes of all embankments have been properly consolidated, formed, and trimmed, they are to be soiled over as specified above, with the soil laid apart for that purpose. Before any ballast is laid on an em-

bankment the surface is to be trimmed to the proper level, and all subsequent subsidences must be made up by ballast alone. All slips or subsidences in the embankment are to be made good to the approbation of the engineer-in-chief, at the contractor's expense, until one year after opening the line throughout this contract for public traffic. No allowance will be made for any collapse of the material of which the bank is composed, or yielding of the ground on which it is formed.

6.—DWARF WALLS.

Should dwarf walls be considered desirable by the company's engineer, the contractor shall build them throughout such lengths of the cuttings as shall be pointed out. These walls are to be eighteen inches thick at the top, plumb at the back, battering one in four on the face, and not more than four feet six inches high over formation level, and coped with two courses of three-inch sods, laid on fresh before the slopes are soiled over; they are to be founded at the depth of twelve inches below formation level. These dwarf walls are to be of substantial dry stone-work, with thorough bonds, not more than one yard apart; face-work to be neatly pinned and laid flush; should rock be found in any of the cuttings, of such a description as to do away with the necessity of these dwarf walls, it is to be cut to range with the walls, and to join neatly with them; the distance between dwarf walls at formation level to be fifteen feet.

7.—DRAINAGE.

The contractor shall construct drains along the foot of slopes, or the sides of dwarf walls in the cuttings. They are to be twelve inches deep below the formation level, and twelve inches wide, as shown in the cross-sections. These

drains to be laid twelve inches below the formation level. When the land-drains or ditches adjoining the railway are deeper than the fence-drains, specified hereafter, the contractor is to increase the depth of said fence-drains or ditches, so as to carry off the water from said land-ditches to the nearest culvert under the railway, or else to such other conveninet level or discharge as the resident engineer shall direct, and no extra charge is be be made on account of such increased depth in the fence-drains. The contractor is to clean out and deepen all water-courses leading to and from any bridge, culvert, or drain, or running along any road, wherever the resident engineer may direct, without any extra charge for the same. The contractor is also to sink the gripes of the railway fences so as to prevent any lodgment of water in them, and so as to have a fall to the nearest culvert or outlet for water.

8.—FENCES.

Where pointed out by the resident engineer, the fences are to consist of a ditch and mound, with thorn quicks. The ditch to be seven feet wide at top, five feet deep on the plumb line, and two feet wide at the bottom. The mound to be five feet high, two feet wide at top, and seven at bottom; it is to be faced with green sods, cut three inches thick, and fifteen inches broad, laid on the flat, and a green sod two feet wide is to be laid on the top of the mound; the thorn quicks are to be planted in the face of the mound, one to every four inches. The quicks are to be provided by the contractor, of the best quality, not less than three years old, and planted in a careful and workmanlike manner, at such times and in such seasons as may be pointed out by the resident engineer. Where the nature of the ground will not admit of these

fences, the fences will be walls of substantial dry stone-work, with thorough bonds, not more than one yard apart, coped with good Scotch coping laid in mortar, and pointed and dashed on both sides. These walls to be of the form and dimensions shown on drawing No. . Should any other description of fence be required by the engineer during the progress of the works, the contractor is to construct it accordingly; and if the price of such altered fence be not in the schedule of prices before referred to, and should any difference arise as the price to be paid for such altered construction, the engineer-in-chief is to decide between the company and the contractor. Wherever any of the field fences abut on the railway fences, they are to be cut through at the time of making the railway fences, and dry stone walls are to be built across the railway ditches, to prevent cattle straying along them; these walls to be 18 inches thick, four feet high over the surface of the ground, and coped with Scotch coping laid in mortar; a drain or opening is to be left in the bottom for the water; no charge to be made for these cross-walls.

The contractor is to repair and clean out all fences made by him, and to keep them in perfect order till the work is taken off his hands. He shall also weed perfectly all fences made by him, once in the month of June and once in the month of September, each year. At embanked bridge approaches the fencing of the railway is to be continued up the slope of the approach to the end of the parapets by a post and wire fence, consisting of posts of the best red pine or larch, four inches square, six feet long, to be driven two feet into the ground, and four wires, No. 5 gauge; no extra charge to be made for these wire fences.

If wire fencing be required by the engineers, it is to be erected with Francis Morton's patent winding straining

brackets, and with wires and posts as specified below for each description of fence.

1st.—FENCE WITH TWO WIRES, of No. 4 wire, Birmingham gauge, with one straining post to every 200 yards, of red pine, five inches by five inches, and five feet six inches long, and intermediate posts of larch, four inches by four inches, by four feet six inches long, ten feet apart, driven two feet into the mound.

2nd.—FENCE WITH THREE WIRES, of No. 4 wire, Birmingham gauge, with one straining post to every 200 yards, of red pine, five inches by five inches, and six feet long, and intermediate posts of larch, four inches by four inches, and five feet long, ten feet apart, driven two feet into the mound.

3rd.—FENCE WITH FOUR WIRES, of No. 4 wire, Birmingham gauge, with one straining post to every 200 yards, of red pine, six inches by six inches, and six feet six inches long, and intermediate posts of larch, four inches by four inches, and five feet six inches long, driven two feet into the mound or ground, ten feet apart.

4th.—FENCE WITH SIX WIRES, the two top wires of No. 3 wire, Birmingham gauge, and the four lower ones of No. 4 wire, with one straining post to every 200 yards, of red pine, with intermediate standards of larch or red pine; the space between the standards to be seven feet. Stays of the same dimensions as the standards to be placed on an average of one to every sixth standard. The straining posts to be of red pine, six feet six inches long, and six inches by six inches square, furnished with red pine sole-pieces, each six feet long, eight inches by four inches. The intermediate posts to be of red pine or larch, free from bark, six feet long, and six inches by four inches in smallest section, placed seven feet apart; all posts to be well tarred.

Every straining post to have one of Francis Morton's patent winding straining brackets, in cast-iron, for each wire, with winding barrel and galvanized pall complete, for straining the wire perfectly tight, to be securely fixed with screws three and a-half inches long, four screws to each bracket.

The wires to be equal to the sample to be seen at the engineer's office, covered with a coat of good tar varnish, to be fastened to the intermediate posts (when of wood) by staples, and to be thoroughly strained upon the barrels of the winding straining brackets.

Where used on ditch and mound fences to railway, should two breaks occur within a distance of 200 yards, a straining post will be required at the end of each such break, and no allowance be made should the total number of straining posts required exceed on the average one to every 200 yards.

Should the engineer require wire of different gauges from those specified to be used, or cable strands to be substituted, the addition or deduction caused by such change to be left to the engineer-in-chief.

"Ditch and mound with four wires" to consist of ditch four feet wide at top, two feet wide at bottom, and three feet deep. The mound to be of same dimensions inverted, both sides to be faced with sods; wire fence on top to be same as above specified for "fence with four wires," except that the intermediate posts are to be seven feet, six inches long, driven through the mound and twelve inches into the solid ground. Thorn quicks, as before specified, to be planted on top of mound, not more than four inches apart. The top twelve inches of the mound to consist of soil in which the quicks are to be planted.

9.—BALLASTING.

The whole extent of this division of the railway is to be ballasted to the depth of twelve inches. The width to be twelve feet at top, rounded off at the shoulders, as shown

in the drawing No. . The ballasting is to be strong clean gravel or broken stone, with sufficient gravel or sand laid over it to form a level bed for the sleepers. The lower six inches may consist of stones laid by hand, not measuring more in any direction than six inches. The upper six inches, if of broken stones, must be broken sufficiently small to pass through a two-inch ring, and be broken in depôts or heaps, which heaps are to be inspected and approved of by the resident engineer before being sent out as ballast. The quality of all stone used for ballast to be subject to the approval of the resident engineer before being broken. This ballasting is to be provided, carried, and spread on the railway by the contractor, but not until the engineer is satisfied that the embankments are consolidated, and the surface of embankments and cuttings prepared and levelled, and brought to the rates of inclination marked on the section, as the finished levels of the railway, and the water-tables properly sunk.

10.—BOXING.

The contractor is to provide good boxing material and to lay it on the ballast to the depth of six inches. This boxing is to consist of clean gravel or coarse sand, where such can possibly be procured at a reasonable expense; (no fine or drifting sand will be allowed;) and if such gravel or coarse sand is not to be had, then it is to consist of broken stones, such as will pass through a one-and-a-half inch ring in any direction, the whole to be levelled and raked in a neat and workmanlike manner, and covered with two inches of gravel or coarse sand, if stone be used as boxing; and the whole finished off to the curve shown in the drawing No.

11.—DIVERSION AND ALTERATION OF ROADS.

Whenever a road is raised, sunk, or diverted, the inclination, headway, and width to be given to it is to be according to the Act of Parliament in each particular case, and the said inclination must be maintained and kept good by the contractor, during the whole term of duration of his contract for the rest of the works in this specification, and all such altered roads must receive coats of metal in the first instance as follows:—In embankments dry pitching six inches deep, and metal, broken so that no stone will measure more than two inches in largest diameter, for turnpike roads nine inches deep, county roads six inches deep; in cuttings and level diversions no pitching, metal same as before; in all farm roads six inches thickness of the same metal only; in every case to be blinded on the top with not less than one inch deep of fine gravel or sand, and the contractor is bound to renew and repair said metalling during the whole term of his contract, and to employ men for that purpose, and to rake in ruts whenever required to do so by the resident engineer, and to keep good the fences of same; failing any of which, the resident engineer to employ men, and to spend such sums as he may think necessary to keep same in order, and to deduct such sums from next monthly or other following payments to the contractor. Also, during the alteration of such roads, where cutting or embanking is required, the contractor is to form temporary roads and bridges, and to keep same in good order, and well and sufficiently fenced, to the satisfaction of the resident engineer, and lights to be placed thereon at night (duly watched) to such extent as he shall require for the public safety; failing which, said resident engineer may order and maintain such lights, watchmen,

and fences, as he thinks fit, and charge same to the contractor. The public are not to be obliged to pass over any temporary road for a longer time than is allowed by Act of Parliament.

The slopes, both in the cuttings and embankments of approaches to bridges, are to be in general one and one-half horizontal, to one perpendicular; eighteen-inch drains, if others be not specified, are also to be placed under the embankments and wing walls, or in other positions according to the nature of the approach, so that a communication may be made between the railway fences on each side.

There is to be a permanent fence erected along the top of the embankment on both sides of every raised road, as shown on drawing, No. , to consist of a dry stone wall of the form and dimensions shown on drawing, No. , coped with Scotch coping laid in mortar, and pointed and dashed on both sides.

These fences are to extend to and join into the old fences at the commencement of the alteration; also, a fence, same as specified for the fence of the railway, is to run along the bottom of each slope of all embanked roads, and along the top of each slope of roads in cutting. These fences and road approaches are to be kept in order by the contractor for after the opening of the line throughout for public traffic.

NOTE.—Wherever there is not sufficient earth to be had in the adjoining excavations for raising any roads over the railway, the contractor is to purchase lands for side cuttings at his own expense.

12.—BRIDGES, CULVERTS, &c.

Under this head will be comprehended the following works, viz.:—erecting and completing—1. The masonry. 2. Timber. 3. The iron-work in the bridges over and

under the railway, as specified in each particular work. 4. Providing and laying concrete in the foundations or elsewhere. 5. Excavating foundations of bridges or culverts. 6. Backing or punning bridges or culverts. 7. Brick-work in culverts and arches.

NOTE.—These general rules for bridge-work are not to vitiate anything specified in the description of any particular bridge.

1. STONE MASONRY.—The stone to be used for rubble and hammer-dressed work must be the most durable stone of the country; for ashlar work, copings, &c., the stone to be from the purer limestone or granite quarries, or such stone as the engineer-in-chief may direct; but all the stone to be taken from such quarries as the resident engineer, or engineer-in-chief may approve; and no doubtful or shivery stone is to be used on any pretence whatever, and will be rejected by the resident engineer, if discovered in any part of the work.

All stones to be laid on their natural bed, and all well packed, pinned, and pointed.

All the outer work of each bridge is to be of stone of the same colour; it must all be neatly pointed after it is put together, and the courses in similar parts to be of corresponding thickness and appearance. In general the height of the courses may be diminished from the foundations upwards, but no two adjoining courses may differ more than two inches in height, and no course to be more in height than the course immediately underneath it.

The contractor must provide a suitable platform, on which the resident engineer will mark out the form of the arches to which the centres must be brought previous to being set up. The contractor to be wholly

responsible for the stability of all centres and scaffolding.

The MASONRY will consist of the following different descriptions, which will be referred to in the particular specification for each bridge :—

No. 1.—FOUNDATIONS are to be of large flat-bedded stones, no stone less than six inches thick, or less than five superficial feet on the bed, laid in hydraulic mortar; all foundations are to be carried down to the solid ground, and, if this should require more masonry than is shown on the drawing, or specified, it will be paid for as extra, if ordered in writing by the engineer.

No. 2.—RUBBLE in facework, backing, counterforts, haunching, &c., to be in courses of from ten to eighteen inches high, of good sound workmanship, carefully laid full in mortar; if backing, in courses of the same height as the facework, with which it must be properly bonded, and in all of this masonry there must be a due proportion of large stones. The rubble in facework is to be of roughly squared stones as closely jointed and bedded as possible; no spalls shall be used in any part, nor shall any stone measure more either way on the face than on the bed.

No. 3.—RUBBLE in range walls, &c., to be in courses carefully bonded with throughs in each course, not more than five feet asunder; no stone to be set on its edge; no dry work to be in the centre of the wall, and the bond on the face to be carefully attended to; all joints, &c., to be neatly struck with the trowel.

No. 4.—ROCK-WORK to be in courses, no stone to be less than nine inches high or ten inches deep, the same proportion of height and depth to be adhered to if the courses are made larger, dressed fair and full to the square on both beds and joints; no stone to be shorter on the face than twelve inches for a nine-inch course, and greater proportional length if the course is higher than nine inches; the bond on the face not be less than five inches, and the facework bonded into the backing by headers on each course, not more than five feet apart, and two feet six inches long each; the stones to be pitch-faced, so as to show a rough projection on the face; the larger courses to be next to the foundation; in all cases the backs of the stones must be scappled to a vertical surface.

No. 5.—HAMMER-SQUARED WORK in wing walls, &c., to be in courses of hammer-squared stone, squared full back on beds and joints, no stone to be set on edge, to be less than four inches thick, or to measure less on the bed than in height on the face, the bond on the face to be at least four inches, and to be bonded into the backing by headers on each course, not more than three feet asunder, and two feet long; these headers to be at least ten inches on the face.

No. 6.—HAMMER-SQUARED WORK in walls to be similar to No. 5, except that it is to have two faces, and that the headers specified there must be replaced with throughs.

No. 7.—HAMMERED FACE-WORK to be the same as specified in Clause No. 5, except that the joints need not be vertical.

No. 8—DRESSED WORK, 1st class, coping. caps, block in course, &c., to have a tooled draft one inch wide on all the arrises, except the joints, to be of the exact form and dimensions shown on the drawings; and sparrow-picked or finely punched on all exposed surfaces; no stone to be less than two feet long, squared full back on beds and joints, except when curved, when it must be dressed so as to joint properly; all the stones to be connected together by iron dowels, one inch square, sunk four inches into the centre of each stone, and run in with cement. In splayed wings the joints of the coping to be in all cases parallel to the face of the bridge.

No. 9.—DRESSED WORK, 2nd class, for impost, string course, &c., to be of the exact form and dimensions shown on the drawing; to have a tooled draft on each face at the several arrises, except at the joints, and to be sparrow-picked or finely punched on all projecting surfaces; all stones to be at least two feet long, squared full back on beds and joints.

No. 10.—ROCK ASHLAR in quoins, to be of stone approved of by the resident engineer, to be of the dimensions specified in the description of the several bridges. All stones to be the height of the course, with perfect beds and thorough joints. All arrises to have a neat tooled draft, one inch broad on each face.

No. 11.—RING PENS to be not less than twelve inches thick on the soffit, of the full depth shown on the drawing, and to bond into the arch one foot nine inches, and two feet nine inches alternately; to be dressed on the beds to the proper summering (and if the bridge be skew, to the twist) of the arch where laid, and full to

the square on the joints; to be chisel-drafted on all the arrises; to be chamfered one inch on face, soffit, beds, and joints, and to be set out one-inch from the rest of the work.

No. 12.—ARCH SHEETING, 1st class, to be of dressed stone, punched on the beds to the proper summering throughout, and, if the bridge be skew to the twist, and squared full back on the joints; all stones to be of the full depth shown on the drawing; the bond on the face to be at least eight inches, this work to be laid in courses of equal thickness with the ring pens; all stones to be of the full thickness of the course. After the centres are struck, all this work must be pointed very neatly.

No. 13.—ARCH SHEETING, 2nd class, to be of rubble, all the stones to be flat-bedded, no stone to be less on the bed than three-fourths of the depth shown on the drawing, and at least one-half of the stones to be the full depth, the backs of the stones to be properly wedged and grouted with liquid mortar.

No. 14.—All moulded work to be of chisel-dressed stone, and to be of the exact form and dimensions shown on the drawings.

No. 15.—HAMMER-SQUARED COPING to be of stones alternately exactly nine inches and twelve inches high, all the stones to measure uniformly nine inches wide, and one foot six inches on the bed; to be neatly squared full back on both beds and joints, and closely jointed.

No. 16.—SCAPPLED COPING to be of stones not less than two feet long, eight inches high, and one foot six inches wide, to have perfect beds and joints, to be pitched to a straight line at the back, and to have a chisel-draft on the face and joint arrises.

In all copings, string course, caps, &c., the joints to be raked out and neatly pointed with Portland cement immediately after being set.

2.—TIMBER.—The timber used in the piles, girders, main ribs, wall-plates, cross-heads, struts, braces, and hand-rails, and all other framed work, to be of the best crown Memel, and the sheeting and flooring to be of red pine. All the timber to be squared, smoothly wrought, and closely jointed and painted with two coats of best oil paint, after being in place; the priming coat to be laid on before the work is put in place; all the joints to be carefully filled

with white lead. All tenons to fit the mortices, and to be well pinned, and no shaky or unsound timber to be used.

3.—IRON WORK.—The wrought-iron used in straps, stirrups, tie-rods, bolts and nuts, boiler plate, angle iron, rivets and bars, to be of the best Staffordshire iron, subject to a test of twenty-two tons per square inch, for which purpose the contractor must provide samples of such dimensions and in such numbers as the engineer may require, without extra charge. All cast-iron to be subjected in like manner to trial tests, and to be of the best quality, free from all air-holes, flaws, and defects of form. In the case of large castings, such as girders, two sample test-bars, each three feet six inches long, one inch wide, and two inches deep, shall be cast of the same metal, and by channels from the casting. One of these bars shall be placed on supports, three feet apart in the clear, and a weight of one and a-half tons shall be suspended by a knife-edge from the middle point of the bar without the intervention of any lever. If the bar fail, the other bar shall be similarly tried, and if both fail under this test, the casting with which they were run shall be rejected, and broken by the contractor's workmen. All large iron work to receive one coat of red lead paint before leaving the workshop, and as soon as in place a coat of naptha varnish, or such other paint as the engineer may direct.

4.—CONCRETE.—The concrete shall consist of good coarse gravel, perfectly free from loam or clay, and ground unslaked hydraulic lime or cement, as required by the engineer, in the proportion of   measures of gravel to one of lime, to be beaten up with a proper quantity of water, but it is not to be mixed up until wanted for use. If broken stone be used instead of gravel, it must be of stone approved of by the resident engineer, finely broken, and passed

through a screen of one and a quarter inch opes. The concrete is to be used where pointed out by the particular description of the bridge, and wherever required by the resident engineer.

5.—EXCAVATING FOUNDATIONS.—The foundations are to be excavated sufficiently deep to secure a solid and uniform bearing. Should the contractor remove a greater depth of earth than shown on the plans, without having been required to do so by the engineer, he shall fill up the excavation with concrete or masonry, similar to that specified for the foundations, and shall not be allowed for this additional work. In case the foundation should be required by the engineer to be carried lower than is represented in the drawings, the contractor shall execute the same where so directed in writing, and shall be allowed for the additional excavation and masonry, according to the prices set forth in the aforesaid schedule; and he shall be allowed, in like manner, for concrete placed under the foundations or in other situations, by direction of the engineer, in cases where the same has not been specified or shown on the aforesaid drawings. Should it be found necessary to make use of pumps, the pump must be placed at least six feet from the nearest masonry.

6.—BACKING OR PUNNING.—All masonry, except where puddle is specified, is to be backed with two feet of dry stones or shivers, closely packed and clean, so as to permit water to pass freely through to small openings which are to be left at the bottom and other parts of retaining and wing walls. The earth outside these dry stones to be well rammed and punned, in courses not exceeding nine inches at a time, and for a depth back of nine feet, also over the arches and between the spandrils. The materials used to be good clay or other dry earth, approved by the resident engineer.

7.—BRICK-WORK.—The bricks shall be from kilns approved of by the engineer—sound, well shaped, thoroughly burnt, and of uniform colour in the face or exposed work. No bats shall be used, and no joint of mortar shall exceed a quarter of an inch in thickness. No difference will be allowed between outside and inside work, and the whole of the joints shall be flushed up solid with mortar or Portland cement, as the resident engineer may, from time to time, direct, and the outside joints neatly drawn and pointed. The bond to be . All arches to be of concentric half brick rings.

13.—LIME MORTAR.

The mortar to consist of fresh-slaked lime, to be approved by the resident engineer, and clean sharp sand; the lime to be the best the country affords, and mixed in the proportion of two of sand to one of lime. The mortar must be mixed in a dry state, and well tempered with a proper quantity of water. All the mortar used shall be fresh made, and if not so, will be rejected.

14.—CEMENT MORTAR.

The cement shall be of the description required by the resident engineer, of the best quality of its kind, from manufactories approved of by the engineer-in-chief, and shall be mixed in the proportion of one measure of cement to of clean sharp sand. It shall be mixed immediately before being used, and none shall be used which has become hard, set, or in any way deteriorated. The resident engineer will direct in writing, from time to time, such portions of the brick-work or masonry to be set in cement as he may think necessary.

15.—PUBLIC ROAD LEVEL CROSSINGS.

There are to be public road level crossings. The gates, piers, &c., are to be of the form and dimensions shown on drawing No. . The gates to be of the best Staffordshire iron, and hung on

An eighteen-inch drain to be laid under the approaches to the gates, and to run into the railway ditches, and a nine-inch glazed stone-ware pipe to be laid on each side of the ballast for ten yards, so as to continue the water tables past the crossing. There are to be four slide bolts, one on each gate; they are to be of one-inch round iron, made so as to slide three inches into a stone socket, to secure the gates in their proper places. The stones for the sockets are to be one cube foot, and are to have holes punched in them, three inches deep, to receive the slide bolts; they are to be placed as shown on the drawing, so as to allow the gates to be fastened across the railway and across the road.

Four-inch oak planks, twelve inches wide and twenty-five feet long, are to be firmly spiked to the railway sleepers, on the inside of each rail; the planks to be guarded on the side next the rails by wrought angle-iron, three inches by two inches, by half inch, firmly screwed to the plank; the screw-heads to be counter-sunk; the space between the gates to be metalled to the top of rails.

16.—FIELD GATES AND CROSSINGS.

The field gates to be of the best Staffordshire iron, of the form and dimensions shown on Drawing No.
and hung on

and a stile as shown on the drawing made at one side of each gate. An eighteen-inch drain is to be laid under each approach to the gate six yards long, to run into the ditches of the railway fence at each side, and a nine-inch glazed stone-ware pipe, to be laid on each side of the ballast for four yards, so as to continue the water-tables past the crossing. Three-inch red pine planks, twelve feet long, are to be firmly spiked to the railway sleepers, on the inside of each rail; the planks to be guarded on the side next the rails by a bar of iron, two inches broad and three-quarters of an inch thick, strongly spiked to the plank; the spike heads to be countersunk. The whole of the approach is to be formed and metalled between the boundaries of the company's land to the satisfaction of the resident engineer. The contractor is to provide a good padlock, with two keys, for every gate. This padlock is to be fastened to the gate by means of a chain.

17.—PERMANENT WAY.

The contractor is to lay the permanent way, and keep same in good repair until one year after the line is opened for traffic, and for so doing is to find all materials, tools, workmen, &c., except the permanent rails, chairs, bolts, spikes, and sleepers, which will be provided by the company, and laid down at

or in such places and quantities as the contractor and resident engineer may agree on; (and should they differ, where the engineer-in-chief may point out.)

The rails must be carefully laid, with their sleepers, bolts, spikes, screws, &c., in their proper places, and to the proper

levels, (and must be also kept packed up to same till after the line is opened for traffic,) which levels will be pointed out by the resident engineer, to whose satisfaction the whole of this work is to be done; and, should he not approve of any of it, he may get it done himself, and deduct the expense of same from any moneys at any time due to the contractor by the company. The contractor will be allowed to carry for the permanent way and boxing (the ballasting being previously completed) on the permanent way, if his waggons have proper springs, wheels at least three feet high, and are approved of in every respect by the resident engineer.

Whenever any of the materials for the permanent way have been laid down at any of the places agreed upon, the contractor or some person authorized by him for the purpose, must take charge of them, and be accountable for them till the work is taken off the contractor's hands, when, should it appear that any of the materials are lost or missing, the cost of same will be deducted from the sum due to the contractor at his final settlement; and should there be no person ready to take charge of them whenever they are ready for delivery, the resident engineer may appoint any watchman, storekeeper, &c., that he may think necessary, and charge the expense of same to the contractor.

18.—CULVERTS AND DRAINS.

The culverts and drains on this contract are to be built at the several places marked on the section, or in such places as the resident engineer may direct, and of such length and dimensions as he may require. The contractor is to cast out foundations for all culverts and drains to such a depth as the resident engineer may direct. The sides and wings are to be of rubble masonry, laid in courses

properly bonded and pointed; the arch stones to be not less than four inches at the smaller end, hammer-dressed, so as to radiate; they are to be laid so as to have a bond on the face of at least five inches, and are to be not less than twelve inches long. In all other respects the masonry to be as specified under the head "Bridges, Culverts, &c." Inverts are to be laid in the culverts of the form and depth shown; these inverts are to be of workmanship and materials similar to the arches. The drains are to be flagged at bottom with flags four inches thick, let four inches under each side wall, and are to be covered at top with flags five inches thick, and having at least six inches on the side walls. The form and dimensions of the several descriptions of drains are shown on Drawing No.

The contractor is to rake out the joints of the masonry of all culverts and drains, and to fresh point them with Portland cement.

All the masonry of all culverts and drains is to be laid full in mortar, as already specified.

The prices of culverts in the schedule are to include all excavation.

The contractor to turn round and securely join the railway fences to the masonry of the culverts, making such junctions with dry stone walls or pitching, if necessary, without any extra charge.

19.—PILING.

The timber used in piles to be of red pine, memel, beech, or elm timber, as specified in the particular description of each bridge, or as ordered by the engineer. The timber used shall be subject to the approval of the resident engineer, who will reject any piles that do not come up to the required dimensions in any way, or that may be

inwinding on any side, crooked, unsound, or faulty in any respect.

The engineer may reject any pile, no matter at what period of the work the unfitness may be discovered, and the contractor must draw such, should they be discovered when driven.

The piles must be accurately pointed, and the shoes carefully fitted, without the least play, and so as to have the points of shoes in the centre line of piles. The dog-nails to be countersunk, so that the heads shall not stand above the surface of the shoes. The shoes to be used to be of wrought-iron, weighing 20 pounds each when the piles are whole balk timbers, and 15 pounds when half balk timbers, in sheet piling or elsewhere, and of the form and dimensions shown on drawings.

The piles must be accurately driven in the places marked on the drawings, and should any pile be driven out of line, it must be drawn and re-driven.

A hoop is to be fitted to the top of each pile, to be taken off and refitted whenever the head of the pile turns spongy under the monkey, and is consequently cut off. No pile will be considered properly driven until a fifteen feet blow from a monkey, weighing 15 cwt., will not drive it more than one-eighth of an inch at each blow.

When the piles are rung and shod, the resident engineer will inspect and mark them near the head if approved of, such mark on no account to be destroyed.

In case of the mark being destroyed without express permission of the resident engineer, such pile shall be drawn, even if wholly driven.

20.—PITCHING EMBANKMENTS

To be of large flat-bedded stones, no stone to be less than

four cubic feet, the bed to be set level on the face and inclining towards the back, at right angles to the batter on the face. The depth to be 2 feet 6 inches. The whole to be of proper workmanship to the satisfaction of the resident engineer.

21.—DRY RIVER WALLS

To be of stones as specified for pitching embankments. To be 2 feet wide on top plumb on back, and battered 1 in 4 on face.

22.—TUNNELS.

Where tunnels are marked on the sections the contractor is to execute them according to the section shown by Fig. No. 1., on drawing No. . Should he be directed to sheet the tunnels, he is to do so according to Fig. No. 2 or Fig. No. 3, as pointed out by the resident engineer.

A fixed price per lineal yard will be put in the adjusted schedule for each section, by which prices the contractor will be paid for the tunnel on final measurement as if such quantities of each description of tunnel were originally specified, such prices to include all scaffolding, centres, drainage, and all other expenses involved in the construction of the tunnel, and also a covered 12-inch drain on each side of formation level.

The rubble masonry to be as specified in Clause No. 2 under the head-stone masonry.

Should the contractor have taken out any portion of a tunnel according to section, Fig. No. 1, he shall, if required by the resident engineer, enlarge same, and sheet it as shown on Fig. No. 2, or Fig. No. 3, without any extra charge beyond what he would be entitled to if it were

ordered to be executed according to Figures No. 2 or No. 3 in the first instance.

[Here follow the descriptions of all the bridges—one example is given.]

DESCRIPTION OF BRIDGE No.

—————————BRIDGE.

This bridge is to carry the railway over the river ; it is to be of the form and dimensions shown on Drawing No. .

The foundations are to be laid on piles, at the depth shown on the Drawing or at such other depth as the resident engineer may direct.

The piling is be carried out according to the following directions :—At each corner of each abutment, and in the middle of the front and back a pile 12″ × 12″ is to be driven, and the spaces between these piles—sides and ends—to be filled up with sheeting piles driven closely together, and secured by waling pieces 12″ × 6″ all round, inside and outside, bolted together through each pile with ¾″ bolts and nuts; within the box thus formed are to be driven 4 rows, (8 in each row) of piles 12″ × 12″, each row to be secured with a waling piece, 12″ × 6″, bolted through each pile. These piles to be all red pine and driven in accordance with the directions under the head PILING in the general specification. The tops of these bearing piles are to be cut off truly in one horizontal plane, and the whole covered with red pine planking 4″ thick, spiked with good dog spikes to every wale.

Concrete is to be laid on top of the planking to a depth of 4 feet, and then the masonry is to be commenced and carried up to within a height of 7 feet of the bottom of the girders, full in cement mortar, and from that level up in lime mortar. The foundations are to be in two steps of 2 feet each in height, and of rubble masonry as in Clause No. 1.

The backing of abutments is to be of rubble masonry as in Clause No. 2.

The front and sides of the abutments are to be of hammer-squared work, as in Clause No. 5, for the whole height.

The string course is to be 2nd class dressed-work as in Clause No. 9.

The caps to be 1st class dressed-work, as in Clause No. 8.

The parapets to be as in Clause No. 6. All under the head "stone masonry" in the general specification.

The superstructure is to consist of two side box-lattice girder beams, carrying cross-girders covered with 4″ red pine planking.

The box-lattice girders are to be each 47 feet 6 inches in length, consisting of an upper and lower flange of boiler-plate 18 inches wide and $\frac{1}{2}$ inch thick, each connected to the lattice sides by four angle-irons $3\frac{1}{4}'' \times 3\frac{1}{4}'' \times \frac{1}{2}''$ each, riveted to the plate by $\frac{3}{4}$ inch rivets placed 4″ apart centres, the rivets breaking joint crossways on the plate. The plates to be in lengths of not less than 12 feet, except at the ends. The angle-irons to be in not more than two lengths each. No two joints, whether of plates or angle-irons, are to occur within a distance of two feet measured vertically.

The lattice-bars to be of the dimensions figured on the drawing, riveted to the angle-irons, and each other at each crossing by rivets, $\frac{3}{4}''$ diameter, riveted hot in holes $\frac{1}{16}$ inch larger than the rivets.

A vertical plate, $\frac{1}{2}$ inch thick, to be introduced on each side of each girder at each end, to strengthen the girder.

The rails to be laid on longitudinal timbers, one averaging 10 inches, the other 6 inches thick, cut with the proper cant for the rails ;* between and on each side of the rails, the cross-girders to be covered with planking 4 inches thick, secured by bolts to each cross-girder. The timbers under the rails are to be tied by four $\frac{3}{4}$ inch cross-rods to preserve the gauge. An edging strip 6 inches × 3 inches to be laid on each side, and the whole covered with fine clean broken stone to a depth of 2 inches. All planking to be well tarred before laying.

The contractor must provide and use sufficient means to keep the excavations dry until the masonry is above the level of the water.

23.—OBSERVATIONS.

The contractor may not himself, nor shall he permit any one else, to cart, drive, or ride along the line of railway, when once the ballasting and boxing, or any part of them, has been laid down, without the permission of the engineer.

No arch, drain, or other work shall be covered till the

* The difference in thicknesses of these timbers is due to the super-elevation of the outer rail required on account of this bridge occurring on a curve. The super-elevation in *inches* may be taken to be twenty-three times the gauge in *feet*, divided by the radius of the curve in *chains*. This is based on a velocity of thirty miles an hour.

resident engineer has inspected it, nor then without his consent; should it be done, he may order the covering to be removed, and if the order be not immediately complied with, may have it done at the contractor's expense.

The resident engineer will give the contractor, for every bridge about to be built, levels for the bottom of the foundations, and pegs for the centre lines of the bridge; the foreman mason must lay off the foundations. Should these level or line pegs, or any others, given to the contractor from time to time, be lost or injured through his neglect, or that of those in his employment, he shall forfeit for every peg so lost or injured, five pounds.

Any directions, whether verbal or in writing, given during the progress of the works, to any of the sub-contractors, managers, overseers, foremen, gangers, or others acting for the contractor, respecting the particular works under their charge, shall be binding as though given to the contractor himself.

The preceding enumerated works, and the mode of execution, are described in the foregoing specification as to each particular work, and their form and dimensions are represented in the respective drawings, which are referred to in the foregoing specification; should any discrepancy exist between the scale attached to the drawings and the written dimensions, or between the drawings and the preceding specification, or any ambiguity in them, the same are to be referred to the engineer-in-chief, whose decision shall be conclusive; also anything contained either in this specification or the aforesaid drawings, shall be as binding upon the contractor as if it were contained in both. The written dimensions upon the drawings are to be taken in all cases in preference to the scale attached thereto, and the dimensions set forth in the description of the work in preference to either.

All arches are to be covered with a coat of coal-tar and sand, three inches thick, laid on hot or with good clay puddle, as directed by the resident engineer.

All temporary bridges and roads are to be subject to the approval of the resident engineer, whether as to form, dimensions, or materials; they, or any of them, are not to be removed, or otherwise disturbed, without the sanction of the resident engineer, and they are to be immediately removed whenever the engineer shall think proper.

The resident engineer, or any officer of the company, or any person deputed by them, may at any time enter on this contract, and make use of or carry away any materials of any sort, that may be on this contract; and for so doing, may make use of any of the contractor's waggons, rails, &c.; and the contractor shall not hinder or obstruct them in so doing, under a penalty of £50 sterling, for every such hindrance or obstruction, (such penalty to be deducted from his next payment,) always provided, that the persons so carrying away materials, or using the contractor's plant, do make reasonable compensation for so doing; such rate of compensation to be settled by agreement between the contractor and the resident engineer, or if they disagree, by the engineer-in-chief.

24.—PROGRESS OF THE WORK.

The contractor shall commence not later than one month after being put in possession of any portion of land. The whole work to be completed on or before the

25.—GENERAL CONDITIONS.

Should it become necessary, in the opinion of the engineer-in-chief, at any time during the progress of the

works, to increase, diminish, or alter the form or dimensions of any part of the work, the contractor shall comply with any order he may receive from him to that effect in writing. The addition, diminution, or alteration, to be allowed for or deducted according to the rates stated in the contract, or adjusted schedule of prices, and the general contract is not to be vitiated thereby, nor is any per centage to be charged by contractor on any deductions.

The contractor is to provide all necessary machinery and materials for thoroughly draining the works during their progress, whether by drifting, pumping, or other means. Also, all plant, waggons, barrows, tools, and materials whatsoever, for temporary ways that may be required in the execution of his contract, all of which are to be of such a quality and construction as shall be approved of by the resident engineer. Any materials which the resident engineer may deem insufficient, or improper to be used, shall be removed from the ground by the contractor, within three days after notice in writing to that effect has been given to him, or any of his clerks, foremen, or superintendents, or left for any of them, at their offices at the works, or at their usual place of abode ; and, in case of his failing to remove such materials, in the time above specified, the resident engineer shall have the power to cause them to be removed by the most convenient means, and at the contractor's expense. The contractor will be held liable by the company for all damage done to adjoining lands during the progress of the works.

The whole of the work executed under the contract is to be of the soundest description, done in a substantial and workmanlike manner.

Nett measurements only will be allowed and paid for. In case of this contract being annulled, by reason of any

breach of the conditions herein contained on the part of the contractor, he shall forfeit all claim to the balance of moneys, if any be then due to him, from the company, upon this contract.

The contractor is to satisfy himself of *the accuracy of all measurements, sections, and levels, besides borings, soundings, depths of bogs, marshes, &c., as no extra claim whatever will be allowed him, on account of any inaccuracy therein.*

The contractor is to execute the whole of the works as described in the aforesaid specification, according to the working plans, sections, and drawings herein mentioned, to the satisfaction of the engineer-in-chief and resident engineer to the company, who shall have the power to reject materials which are not of the best quality, and to take down, or cause to be taken down, any work which they may consider to be imperfect; or to suspend the further execution of any part of the work till such time as he may think proper. The engineer-in-chief is to decide all disputes, should any arise as to extra work, or as to any other matter which may arise out of this contract, and his decision is to be final and binding on all parties concerned. The works are to be executed within the periods limited, either in whole or successive portions thereof, as stated in the specification. Copies of this specification and of the contractor's schedule are to be deposited with the resident engineer, and the contractor may have access to them.

Alterations or additions to any of the works are to be executed under written authority, signed by the company's engineer-in-chief, without which authority such alterations or additions will not be paid for. Works omitted or reduced by the engineer, are to be deducted for according to the adjusted schedule of prices. The work to be measured by the resident engineer about once in every and payment

to be made by the company, through their secretary or pay-clerk, upon the certificates of the amount recommended to be paid for work executed, by the engineer-in-chief; but any sum which may become due to the company from the contractor on account of damages to lands, or for other things paid for him by the company, shall be deducted therefrom if the company think fit. The contractor is to receive 90 per cent. of the amount due for works executed according to the certificates, and the remaining 10 per cent. to be paid by the company to the contractor, in twelve months after the satisfactory completion of the entire contract under the certificate of the engineer-in-chief.

In case of the workmen employed or the materials provided by the contractor being insufficient for the completion of the works within the period named, the contractor shall, upon notice from the engineer of the company, provide such additional workmen or materials as the engineer-in-chief shall deem necessary; and in default thereof, the engineer shall employ such additional workmen, or provide such additional materials, at the cost of the contractor, and may also deduct the consequent wages and the costs of the materials out of moneys which may become due to the contractor, so far as the same may be sufficient for that purpose; or it shall be at the option of the engineer-in-chief, in case of such deficiency of progress, to annul the contract, on giving to the contractor a written notice, fourteen days previously, to that effect. And if the contract shall be so annulled, the contractor shall forfeit all claim to any moneys or balance that may be due to him on account of said contract.

The contractor is not to use adjoining lands, without consent in writing of the engineer-in-chief. The contractor is not to make bricks or tiles without consent of the said

engineer in writing; nor to use the land for any purpose, nor to put spoil out on any places prohibited by the Acts of Parliament relating to the said railway. The contractor is to make satisfaction and compensation as required by the said Acts to all owners and occupiers, for damages by trespass, by himself or any of the persons employed by him, or by strangers where neglect can be proved; or the resident engineer may award said satisfaction or compensation, and pay it, charging the amount to the contractor.

The contractor is to deliver, at the office of the resident engineer, an account, every month before payment, or when required by the resident engineer, of the number of artificers and other workmen employed on the works during the preceding fortnight, according to a form to be furnished, and pay Five Pounds sterling on default for every such account as shall be omitted.

The directors of the company, or the engineers, to have power to remove any persons in the employment of the contractor on the line, without assigning any reason for so doing, after notice of their intention to do so shall have been given to the contractor; or in the case of workmen or artificers, they may be instantly dismissed, on verbal notice being given to any of the sub-contractors, managers, foremen, or gangers; and if any person shall be still retained in service after such notice of removal has been given, the engineers or directors of the company to have power to deduct the wages of such persons at any rate not exceeding One Pound per week out of the monthly moneys due to the contractor.

The contractor is not to make any sub-contract, without the consent in writing of the engineer-in-chief or resident engineer of the company, except as to labour in the earthwork only.

If temporary roads be necessary, the resident engineer is to set them out, and the contractor is not to deviate therefrom, and is to keep them constantly well fenced.

The contractor, if required by the directors of the company, is to pay the sub-contractors and workmen their full wages (as before mentioned) on any day to be appointed by the said directors, and in the presence of a person appointed by the directors, in such places as the directors may appoint, and no other; the same rule to apply to all payments made by any sub-contractor, and the directors to have power to dismiss every sub-contractor in case of non-compliance.

The contractor is not to retail, either directly or indirectly, without permission of the directors, any article of consumption to the workmen; nor to allow any person in his employment to do so.

The contractor will be required to give his personal attention at all times to such parts of the work as the chief engineer may appoint; to keep efficient foremen always at work, who are to be capable of setting out the levels, slopes, bridges, &c., and carrying out the directions of the company's engineer, and who are to be responsible for the correctness of same, as the company's engineers are not responsible to the contractor for the levels, &c., which they will check for their own satisfaction only.

The contractor, his managers and overseers, are to keep an order book, in which the resident engineer will enter, when he thinks proper, such orders for jobbing work, such as repairs of fences, roads, or any small matters not specified herein, but nevertheless necessary for the proper conduct of the works as may be required from time to time, and for which no extra charge is to be made; and said orders in the book to be produced whenever called for, and if it shall

appear that any such order has not been attended to, within three days from the date of receiving the order, then the resident engineer is empowered to give directions for executing same under his own superintendence, and to charge the expenses thereof against the contractor.

The contractor is not to strike any centres, or throw earth against any masonry, (except the rammed backing) without three days' previous notice in writing to the resident engineer, nor then without his permission, under a penalty of Five Pounds for every such omission.

There can be no extra charge allowed for executing any part of the works alluded to or specified in this specification, except those for which it is herein distinctly stated that an extra charge may be made.

Should any of the works in the contract fail or require repair during the progress of the contract or within
after the completion thereof, the failure or repair must be made good to the satisfaction of the chief engineer, entirely at the contractor's expense.

In the timber and iron bridges, the contractor is to provide and use all necessary spikes, bolts, nuts, straps, and sockets, and all other necessary materials for the proper completion of the meaning and intent of the drawings and specification, though not minutely detailed in those documents; and the weight and calibre of same to be as directed by the resident engineer. And in case of any dispute between the contractor and him, concerning the quality, weight, and quantity of such materials, the matter so in dispute to be referred to the final decision of the engineer-in-chief.

NOTE.—As there is no means of ascertaining the number of occupation-bridges, level-crossings, &c., that may be required, until the agreements have been made with landowners, &c., the contractors are to build them where required, as extra works, at the prices in the adjusted schedule.

NOTE.

Contractors are to send in their tenders upon the printed forms which will be furnished to them. The schedule of prices must be sent in as annexed to the tender; every item, whether appearing in the specification or not, being properly filled up, and the successful contractor is bound to compare the schedule and quantities of work in the contract, with the engineer, before commencing the work, and if the prices in the schedule are such as to cause the total amount when compared to be greater than the actual amount of the contractor's tender, then the schedule of prices must be altered so as to cause the total sum to correspond with the tender to the satisfaction of the engineer; and upon this schedule all the deductions, extras, and alterations that may be ordered in the accepted contract will be valued; and a list of bridges must be also made out, and a fixed value set on each, on the same principles; and until all this is done, the works are not to be commenced, or if commenced, no payments will be made until the final arrangement of the schedule as required above. The parties tendering to put their initials on every page of the schedule and specification at the time of signing the tender.

Schedule of Prices adjusted to amount of contract, and by which extra works, and additions to and deductions from the contract, are to be estimated.

		£	s.	d.
EARTHWORK	... The average price of the whole excavations of clay in railway cuttings, per cubic yard			
	The price of excavation of clay in road approaches and extra works, except foundations, per cubic yard ...			
	The average price of the whole excavations of rock in railway cuttings, per cubic yard			
	The price of excavation of rock in road approaches and extra works, except foundations, per cubic yard ...			
	The price of excavating foundations in clay, per cubic yard			
	The price of excavating foundations in rock, per cubic yard			
	The average price of side-cutting put into railway embankments, per cubic yard			
	The price of side-cutting put into road approaches and extra works, per cubic yard			
	The additional price for clay-cuttings put into embanked road approaches and extra works, per cubic yard ...			
	The average price of excavations in diversions of rivers and streams, per cubic yard			
	The price of excavating foundations of river bridges, per cubic yard ...			
	Removing soil, trimming, soiling, and sowing slopes, per super yard ...			
FENCING	... Ditch and mound fence, as per specification, planted with quicks, per lineal yard			
	Ditch and mound fence, as per specification, but without quicks, per lineal yard			
	Providing, planting, and keeping in complete repair for one year after the opening of the line for public traffic, by renewal, the above, with three-year old quicks, as specified, per lineal yard			

		£	s.	d.
FENCING—*con.* ...	Wire fencing with two wires, as per specification, per lineal yard ...			
	Wire fencing with three wires, as per specification, per lineal yard ...			
	Wire fencing with four wires, as per specification, per lineal yard ...			
	Wire fencing with six wires, as per specification, per lineal yard ...			
	Fences on top of embanked approaches, as specified, per lineal yard ...			
	Fence walls in dry stone, pointed, dashed, and coped in mortar, as specified, per lineal yard ...			
	Dwarf walls in excavated road approaches, as specified, per lineal yard			
BALLAST ...	The lower six inches of ballast, as per specification, per cubic yard ...			
	The upper six inches of ballast, as per specification, per cubic yard ...			
	The boxing, as per specification, per cubic yard			
	The price of the whole of the ballast and boxing when all completed, per cubic yard			
METALLING ...	Road metal, pitching and blinding, as specified, per cubic yard... ...			
MASONRY, as per specification—				
	Rubble in foundations, as in clause No. 1, per cubic yard			
	Rubble in backing, &c., as in clause No. 2, per cubic yard			
	Rubble in range walls, as in clause No. 3, including Scotch coping, per cubic yard			
	Rock work, as in clause No. 4, per cubic yard			
	Hammer-squared work, in face of abutments, &c., as in clause No. 5, per super yard...			
	Hammer-squared work, in parapets, &c., as in clause No. 6, per cubic yard			
	Hammered face-work, as in clause No. 7, per super yard			
	Dressed work 1st class, as in clause No. 8, per cubic foot			

		£	s.	d.
MASONRY as per specification—*con.*				
	Dressed work, 2nd class, as in clause No. 9, per cubic foot			
	Rock ashlar quoins, as in clause No. 10, per cubic foot			
	Ring pens, as in clause No. 11, per cubic foot			
	Arch sheeting, 1st class, as in clause No. 12, per cubic yard			
	Arch sheeting, 2nd class, as in clause No. 13, per cubic yard			
	Moulded work as in clause No. 14, per cubic foot			
	Hammer-squared coping, as in clause No. 15, per cubic foot			
	Scappled coping, as in clause No. 16, per cubic foot			
	Dwarf walls in railway cuttings, as specified, per lineal yard... ...			
BRICKWORK ...	Laid in cement, per cubic yard ...			
	Laid in mortar, per cubic yard ...			
	Fire-brick laid in cement, per cubic yd.			
	Fre-brick laid in mortar, per cubic yd.			
CONCRETE ...	As per specification, per cubic yard ...			
PUDDLE ...	Over arches, per cubic yard ...			
TAR COATING ...	Over arches, as per specification, per super yard			
CULVERTS & DRAINS, as per specification & drawing No.				
	Twelve feet culverts, per lineal yard...			
	Ten feet culverts, per lineal yard ...			
	Eight feet culverts, per lineal yard ...			
	Six feet culverts, per lineal yard ...			
	Five feet culverts, per lineal yard ...			
	Four feet culverts, per lineal yard ...			
	Three feet culverts, per lineal yard ...			
	Two feet drains, per lineal yard ...			
	Eighteen inch drains, per lineal yard			
	Fifteen inch drains, per lineal yard ...			
	Twelve inch glazed stoneware pipe laid in cement, per lineal yard ...			
	Nine inch glazed stoneware pipe laid in cement, per lineal yard ...			
	Six inch glazed stoneware pipe laid in cement, per lineal yard			

NOTE.—These prices for culverts and drains include all excavations.

		£	s.	d.
PERMANENT WAY,	The price of laying a single line of permanent way, (*i.e.*, two lines of rails,) the materials to be delivered by the company, as in specification, per lineal yard			
	Laying points and crossings, per lineal yard			
	Maintenance for twelve months after opening, per mile			
LEVEL-CROSSINGS,	The price of a public road level-crossing as specified, with gates, metalling, guard-rails, and drains complete, as in drawing No. ...			
	The price of a farm road level-crossing, with gates, metalling between company's bounds, guard-rails, drains, and walls complete, as specified, as in drawing No.			
	The price of a single gate and piers, as in drawing No.			
IRON (WROUGHT)	In bars, bolts and nuts, tie rods, straps, stirrups, hinges, spikes, screws, and pins, fitted and fixed, per cwt. ...			
	In girders, fixed with bolts and fastenings complete, including painting, per ton			
IRON (CAST) ...	In wall-plates, fitted and fixed in place, per ton			
	In pipes, including joints, bolts and nuts, and cement, fitted and fixed in place, per cwt.			
TIMBER ...	Framed, trussed, or wrought timber, in bridges, of memel, including painting in three oils, spikes in planking, &c., per cubic foot ...			
	Red pine, framed or planking, planed and painted in three oils, spiked, per cubic foot			
PILING	Memel or red pine in piles, including shaping, driving, shoes and hoops, as per specification, per cubic foot...			
	Beech or elm in piles, including shaping, driving, shoes, and hoops, as per specification, per cubic foot ...			

		£	s.	d.
TUNNELLING ...	As per specification, according to drawing No. fig. No. 1, per lineal yard			
	As per specification, according to drawing No. fig. No. 2, per lineal yard			
	As per specification, according to drawing No. fig. No. 3, per lineal yard			
Here follows the price of each bridge:—				
Bridge No. 1.	... ...			
" " 2.	... ...			
" " 3, &c., &c.	... ...			

THE ESTIMATE.

The different items which compose an estimate *of works* are as follows :—

Trimming, soiling, and sowing slopes,	in	super	yards.
Excavation in clay,	"	cubic	"
Excavation in rock,	"	"	"
Excavation of side-cutting,	"	"	"
Excavation in diversions of rivers and streams,	"	"	"
Excavation in approaches and diversions of roads,	"	"	"
Excavation of side-cutting for forming embanked road approaches or diversions,	"	"	"
Embanked road approaches or diversions formed from railway cuttings,	"	"	"
Ditch and mound fencing with wire paling,	"	lineal	"
Dry stone wall fences,	"	"	"

ESTIMATE—*continued.*

Road metalling and pitching,	in cubic yards.
Ballast and boxing,	„ „ „
Laying permanent way,	„ lineal „
Public road level-crossings,	„ items.
Tunnels,	„ lineal yards.
Culverts (mentioning the different sizes),	„ „ „
Bridges, No. 1.	
„ No. 2, &c.	
Maintenance of way,	in miles.

The first operation is the calculation of the quantity of excavation in the railway cuttings, both of clay and rock.

It is supposed that the office is provided with a copy of Sir John Macneill's earthwork tables, and that the base and slopes adopted by the engineer are among those given in that book.

Sheets of paper are ruled in the same way as shown in Plate 5, or similarly, and the engineer proceeds to fill up the columns as follows.

In the first column he enters the number of the cutting or embankment; in the next, the number of the chain, or chain and decimal of a chain, at which the surface of the ground varies from a straight line; in the next, the difference between every pair in the last column—*i.e.* the length of each block, writing the numbers in the second column *between* the ruled lines, and the numbers in the third column *on* the lines.

In the fourth or fifth column he next inserts the height of embankment, or depth of cutting, as the case may be, omitting decimals and entering the *nearest* whole number.

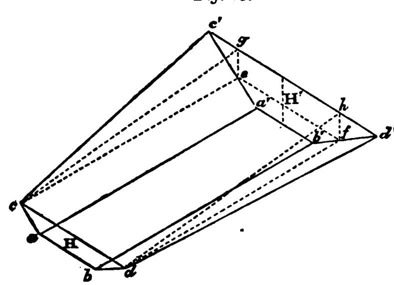
It is the best plan to fill up these columns for the entire length of the line, or of a division thereof, before proceeding to the next step, which is to take out from the table and insert in the sixth column the tabular number belonging to each pair of heights. This also had better be done on all the sheets continuously.

The tabular numbers are then multiplied by the corresponding lengths which have been entered in the third column, and the result entered in the seventh column, headed "Products." The "products" of each cutting or embankment are then added up, and the result entered in its proper column.

The form of these papers may be changed as each engineer thinks well; but the one form only should be used in any one office.

The numbers given in the tables are arrived at in the following manner:—

Fig. 15.



Let $abcd\ a'b'c'd'$ represent the block of a cutting, which has for its heights H and H', for its base $B=ab$, for its length $L=aa'$, and for its ratio of slopes the ratio $R=\frac{c'g}{ge}$

Let the dotted lines ce and df be drawn parallel to aa', and the other lines as shown.

The content Q is evidently equal to the sum of the contents of the figures $abcda'b'ef$, $cdefgh$, and twice the content of the figure $cc'eg$, that is equal to

$$L(BH+H^2R)+L(B+2HR)\left(\frac{H'-H}{2}\right)$$

$$+\frac{2L}{3}\left(\frac{H'-H}{2}\right)(H'R-HR)$$

$$=L\left\{\frac{B(H+H')}{2}+R\left(H^2+HH'-H^2+\tfrac{1}{3}(H'-H)^2\right)\right.$$

$$=L\left\{\frac{B(H+H')}{2}+\frac{R}{3}(H^2+H'^2+HH')\right\}$$

This is known by the name of "the Prismoidal Formula."* All these, it must be remembered, are in the same units, and if it be wished to express Q in cubic yards and L in feet, the expression becomes

$$L\left\{\frac{B(H+H')}{54}+\frac{R}{81}(H^2+H'^2+HH')\right\}$$

The part within brackets is the tabular number of the first set of Sir J. Macneill's tables, and the two parts of it are the separate numbers under the heights H and H′ in the tables to base 1 and slopes of R.

There is another way of expressing the *true* content of a prismoid; it is—to the sum of the end areas add four times the middle area, and multiply the sum by one-sixth of the length.

There are two erroneous rules sometimes used; the first, by taking the section in the middle as the *average* section; and the second, by taking half the sum of the end areas as the *average* area.

The errors arising from each of these methods are seen

* Professor Townsend has given another proof and an investigation into the effect of steep gradients on the quantity of cutting, in the Transactions of the Institution of Civil Engineers of Ireland, vol. ix.

at once, by comparing the content as given by it with the true quantity.

The method of mean heights gives a content of

$$L\left\{B\frac{H+H'}{2}+\left\{\frac{H+H'}{2}\right\}^2 R\right\} \text{ and an error}$$

$$\text{of } -\frac{(H-H')^2}{12}$$

The method of mean areas gives a content of

$$L\left\{B\frac{H+H'}{2}+\frac{H^2+H'^2}{2}R\right\} \text{ and an error}$$

$$\text{of } +\frac{(H-H')^2}{6}$$

So that one method gives an error in excess, the other an error on the other side, and one error is double the amount of the other.

In cuttings it will constantly occur that the contents are not, as above supposed, all rock or all clay, but may be partly rock and partly clay. In this case the rock can be taken out as above, and the clay taken out in blocks the same way as before, with this exception, that each block will have a different base. The approximative method generally used to ascertain the quantity of such clay excavation, is to assume the base of each length to be a mean of the bases at each end, or, what is the same thing, a mean of the widths of the top of the rock-cutting at those points.

This method of getting the quantity of the clay is not strictly accurate. The *true* content of a block of this kind is given by this formula

$$Q = L\left(\frac{B(2H+H')+B'(2H'+H)}{6}+\frac{R}{3}(H^2+H'^2+HH')\right)$$

where B is the base of clay at the end at which H is the height, and B′ the base, and H′ the height at the other end; the error introduced by the approximative method is

$$+\frac{(B-B')(H-H')}{12}L$$

It is to be remarked that this error is to some extent compensating, sometimes being in excess, and sometimes the other way. The approximative method gives too much, if at the same time $B>B'$ and $H>H'$ and too little if $B>B'$ and $H<H'$.

There would be little difficulty in taking it out quickly and correctly, if tables were constructed for the purpose.

Again, cases will occur where none of the rules above given apply, namely, where the ground is so uneven as to require cross-sections.

The best thing to be done in this case is to take the mean of the two areas of the two cross-sections, and multiply it by the length between them, and reduce to yards.

Or they may be treated in such a way as to introduce them into the regular earthwork sheets, by drawing an equating horizontal line on the cross-section, and entering the scaled height of such line in the regular columns of heights.

The earthwork having been calculated, the next thing is to take out the number of superficial yards of soiling required.

Referring to the figure in page 130, it will be seen at once that the soiling for that block is equal to twice the area *bd b′d′*.

$$bd = \sqrt{H^2 + H^2R^2} = H\sqrt{1+R^2}$$

$$\therefore \text{ area of } bdb'd' = L.\frac{H+H'}{2}.\sqrt{1+R^2}$$

$$\text{and the whole soiling} = L.\sqrt{1+R^2}.\,(H+H')$$

In the usual case of clay-cuttings (of course no soiling is required in rock-cuttings) the ratio of slopes $R = \frac{3}{2}$, and consequently the number of superficial yards of soiling $= L. (H + H'). \times \cdot 2$, where L, H, and H′ are in feet, and the results in super yards.

Hence the way to fill up the last column on the paper is to multiply each pair of heights by one-fifth of the corresponding distance.

For other slopes, the best (*i.e.* quickest) way is to multiply each pair of heights by the distance, and the sum of these products by the number $\sqrt{1 + R^2}$.

The quantities should next be collected in an abstract table, and the total made out.

The next item, side-cutting, must be deferred until the earthwork in river diversions, road diversions, and in road approaches, has been calculated.

The excavation in diversions of rivers and streams is taken out in the same way as the cuttings.

Embanked road approaches are taken out similarly to embankments, with a base equal to the width of the road, with an additional width for fences. Three feet six inches on each side, in addition to the width of the road, gives a sufficient base for dry stone wall fencing. Of course, if wooden paling be intended, the width will be greatly reduced.

Excavation of road approaches is usually taken out with dwarf walls, which serve as the road fences; in this case the excavation consists of two items, the lower being a plain block with vertical sides, and the upper a prismoidal solid with a base equal to the width between the top of the two dwarf walls.

When he has marked all these earthwork quantities, both of filling and excavation, in their proper places on the office

copy of the section, the engineer proceeds to *distribute* the earthwork, or in other words, to find out what side-cutting is required for railway embankments, and what for embanked road approaches.

The excess of the total quantity of embankment over the total quantity of excavation will by no means give the side-cutting. Cases have occurred where the quantity of cutting has been greatly in excess of the quantity of the embankments, and a considerable quantity of side-cutting required, and yet the most economical gradients were made use of.

The quantity of excavation in river diversions can be taken as forming part of a neighbouring embankment, without any extra charge, and also road excavations, if situated close to the embankment.

When a cutting over which a road is passed by an embanked approach is insufficient to make up the neighbouring embankment, it depends on the prices at which the engineer calculates the estimate, whether it is more economical to make up the embanked road approach from the railway cutting or not.

For instance, if the price of the side-cutting to embanked road approaches be 10d., and to railway embankments be 8d., and the additional price of shifting earth from a railway cutting to a road approach be 3d. per cubic yard, it will be evidently more economical to make up this road approach altogether from side-cutting, and let the whole of the cutting go to form the embankment.

If the cutting is more than sufficient to form the railway embankment, but not sufficient to form both it and the approach, it would, at the above prices, be best to put down the difference as side-cutting to the approach; while, had the price for side-cutting to the railway embankment been only 6d., it would have been more economical to form the

whole approach from the cutting, and throw the deficiency on the embankment.

There is a length of lead which cannot in practice be exceeded, and which causes the anomaly of a cutting being run to spoil at the same time that side-cutting is provided for an embankment. This length of lead depends generally on the average price at which the earthwork is to be put in the estimate, and on the gradients. This is not reducible to figures, but must remain a matter of judgment.

The next item is fencing. The fencing of the railway may fairly be taken to be continuous along both sides of the line, without any deduction for bridges, level-crossings, or culverts. The lines of fencing are not parallel to the line of rails, and, if perfectly continuous, would necessarily, owing to the variable width of the railway land, be longer than the centre line; this, coupled with the trouble and expense of temporary fences at the gaps, accounts for the above being fair measurement.

No allowance is or ought to be made for additional length caused by undulations of the surface; because the specified section of the mound or wall is measured on a *vertical* section, and consequently the measurement should be taken horizontally. Fencing is always measured in lineal yards.

Next come road metalling and pitching. It is usual to measure these two together, and put them at an average price per cubic yard.

Ballast and boxing may be estimated either separately or together; the former is the more usual practice, but the latter is preferable, as it facilitates the settling in case of a contract being surrendered before it is completed. Both are measured in cubic yards, being together usually about 2 cubic yards per yard run of single line.

Laying permanent way is measured by the lineal yard of line, single or double, as the case may be. Neither ballast, nor laying way, include anything in the way of sidings, which are afterwards to be paid for extra.

Laying crossings and points are paid for at a price per lineal yard additional to the laying of same as permanent way, and always form an extra, as the amount required cannot be told until the contract is finished.

Culverts are classed according to their different spans, as 12 ft., 10 ft., &c.; the 24 in. and smaller being called drains.

Culverts are usually measured on the arch-stones only, that is from ring to ring; no allowance being made at all for the wings or excavation. This is not an universal rule, sometimes *one* wing is measured in.

The bridges are next in order, the bulk price of each being given in the general estimate.

Each bridge estimate comprises the following items :—

Excavation.
Rubble masonry in foundations.
Rubble masonry in abutments, &c.
Hammer-faced or hammer-squared work in facing.
Hammer-faced or hammer-squared work with two faces.
Rock-faced quoins.
Dressed-work.
Arch sheeting.
Puddle.
Iron, wrought.
Iron, cast.
Timber.
Brickwork.

Excavation. The excavation consists of that required for the different foundations.

In taking out the measurements for excavation, it would be unfair to take nett measurements; earth cannot be taken out plumb, therefore some allowance should be made. This is fairly met by adding one-fourth of the height of the excavation to the width at bottom, which allows for a slope of $\frac{1}{4}$ to 1.

For instance, if the excavation for an abutment be sixty feet long, six feet wide at the bottom, and four feet deep, it would be entered on the estimate sheet as

$$60{\cdot}0 \times 7{\cdot}0 \times 4{\cdot}0.$$

With regard to the order in which these numbers should be entered, it should be made a fixed rule, that the first measurement should be in the direction of the centre line of bridge, the second in the direction at right angles to the first, and the third vertical; this is important, as it guides the assistant who checks the estimate, and thus saves *time.*

The next item is *rubble masonry in foundations.*

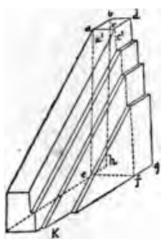
The quantity is given by the product of the length, width, and height: it must be remembered in the case of skew-bridges, that either the length or width must be measured on the square, and the other on the skew. If any small reëntrances occur in the foundation work they are usually neglected, and the work measured full. Rubble masonry in foundations is usually put at a slightly lower price than other masonry, not that inferior work is to be allowed, but because several incidental expenses, such as for scaffolding, &c., are not incurred.

Rubble masonry above foundations.

The measurements of the abutments, the counterforts, haunching, and spandrils, present no difficulty. If the wings are straight back, the measurement is similarly easy; but some difficulty occurs about the

measurement of splayed wings. An example will, perhaps, best show the way of estimating splayed wings.

Fig. 16.



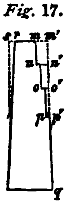
The figure shows a splayed wing completely separated from the bridge; it is designed for a returned parapet, as in Plate 4.

The next figure shows the section of same wing. The first part taken is that which forms the return, *a b c d e f g h;* the measurements of this are

$$cd \times \text{the mean width} \times \text{the height.}$$

The mean width is equal to

Fig. 17.



$$rm' + rs - \frac{mm',\, m'n' + nn',\, n'o' + oo',\, o'p'}{m'q}$$

The sloping blocks from each step up are then to be taken separately, the measurements being the mean length measured on the line *fk*, the mean width (as *d'c'*,) and the height (as *mn*.) It will be seen that this is only approximative for all the blocks below the top one.

Another way of taking out splayed wings, when stepped such as in Plate 4, is to take them in vertical blocks on each step, with an average height and thickness.

In a skew bridge like this, one pair of wings is always longer than the other, though of the same length measured on the square from the face of the bridge. The same applies to the steps. In such cases, to simplify the estimate, the lengths of the steps of the long wing are sometimes added to those of the short wings, and each pair introduced into the estimate as one item, as they have both

the same average thickness and height. This is done in the calculations of the "rubble masonry" in the estimate, which is given in the Appendix.

Hammered work in facing.

This is superficial measurement. The abutments, wings, and outside spandrils are usually hammer-faced. If the wings are straight back, the hammer-facing need extend only to a certain distance below the slope line of the earth; this depth will be found in the "description" of the bridge. By some the hammer-facing is measured cubically, and estimated at a certain depth into the work; of course this must in that case be deducted from the measurement of rubble masonry above.

Hammered work with two faces.

This is in parapets. The measurements are evident. In this case, and wherever they occur, when ashlar quoins are specified, the quantity in the quoins must be deducted from the other work.

Rock-faced quoins (if any.)

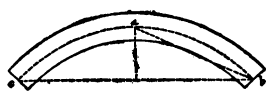
These are the quoins of the abutments, newels, and parapets. If the wings be straight back, the ashlar quoins of the pilasters (which usually terminate the wings) need not go down the whole depth of the wing, but only to a certain depth below the slope of the embankment, usually to the same depth as the hammer-facing is carried, as mentioned above.

Dressed work, first class.

This includes all coping, caps, block-in-course, and ringpens. The coping and caps generally have some

chamfer or moulding; this is not taken into account, and the stones are measured full. The measurements for the ringpens are the mean width × length × height. The mean width is given by the specification.

Fig. 18.



The height is given on the drawing, and the length is obtained in this way. Midway between the intrados and extrados draw the dotted line *b a c*, which is the length of the ringpens. This arc is equal to

$$\frac{8ab - bc}{3}*$$

In case of a skew-bridge, the length must be got by measuring on the elevation, as the depth given by the specification is measured on the coursing spirals or square to the face line of arch.

Dressed work, second class.

This includes stringcourse and impost. The dressed work is not always divided thus into two *classes*, but invariably some distinction in price is made; the reason for this being that coping, &c., have so much more surface *dressed* than stringcourse.

Arch sheeting.

The length is the same as for the ringpens, the height as shown on drawing, and the depth the width of the bridge on the square, deducting the depths of the two courses of ringpens. If there is no impost course the top stones of the face of the abutment

* For demonstration, see article "Mensuration," *Encyc. Brit.*, 7th edition.

should be measured and put at the same price as arch sheeting and ringpens, respectively under the name of "springers."

Arch sheeting may be of two kinds, corresponding to random and coursed masonry, and the latter again may be of two kinds, *gauged* and *broken*.

The best of all is gauged sheeting, in which every stone is the same thickness as the ringpens, and the courses forming fair straight lines from face to face if the bridge be square, or fair spiral lines, if skew.

The next best is where the sheeting is in courses, but each course containing more than one stone in thickness. Courses, in this class, should finish in a ringpen or ringpens exactly. Lastly, the sheeting may be all random work. If random work be used in skew arches, the stones *must* be dressed according to Buck's method; the other methods, such as Harte's, not applying except to gauged sheeting.

Puddle. The measurements are evident.

The measurements are all entered on the estimate sheet in feet and inches, and are then multiplied together and entered in a column ruled for the purpose. The whole quantity of each description of work is then added up and reduced and entered in the next column in the units by which the price is taken. Thus excavation, rubble masonry, brick work, hammer-faced work in parapets, arch sheeting, and puddle are paid for by the cubic yard. Hammered work in facing is paid for by the superficial yard, dressed work, ashlar quoins, and timber by the cubic foot.

In reducing, to cubic yards for instance, the division may leave a remainder, in this case the nearest unit should be taken.

In measuring timber work in bridges the timbers should

be measured to the end of the tenons, and, if cut off at an angle, on the greatest length.

The measurements of the masonry are simple, and will be learned sooner by going over an estimate with the drawing than by any description. The estimate of the bridge in Plate No. 4 is given in the Appendix.

In measuring iron work, great use may be made of a small book, called *Penn's Tables*, which gives the weight per foot, super or run, as the case may be, of iron of all scantlings, both wrought and cast. Where the tables are not handy, the weights may always be found by the rule given in *Clarke's Description of the Tubular Bridges*, viz. :—

> *The weight in lbs. of any uniform bar of wrought-iron per yard run is equal to ten times the number of square inches in its section.*

Thus not only do we ascertain at once that a bar of wrought-iron, one inch square, weighs 3.33 lbs. per foot run, but also that quarter-inch boiler plate weighs 10 lbs. per super. foot.

For cast-iron, one-twentieth of the whole, as given by the above rule, should be deducted.

In measuring girders, the portion of a rivet embedded in the plates is measured in the plates; and in addition three times the diameter in length is allowed for the two heads.

The maintenance of way is generally for one year, and either given in the estimate as a lump sum, or as so many miles, at a sum per mile.

END OF PART II.

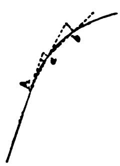
APPENDIX.

A.

LAYING OUT CURVES.

Method by offsets.

Fig. 12.



When the springing points of the curve have been fixed, the curve may be marked in thus:—The chain is to be stretched out from A in the direction of the tangent, and an offset laid off at right angles by which the point *a* is found. The chain is then stretched from *a* in the direction A*a* produced, and a pin put in. A short rod of a calculated length is then put against the pin, and the end of the chain and the other end of the rod held together. Being held thus when the chain is taut, the end of the rod is at a point, *b*, in the curve. This process is repeated until the second springing is reached or passed. This method is very handy when the ground is *very* level, and free from fences; and is of the greatest use in putting pegs on formation level for the laying of the permanent way. It is also very useful for marking out road approaches, and road diversions, with regular curves.

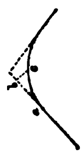
The *first* offset is equal to half the length of the rod. The length of the rod is $\frac{\text{chord}^2}{\text{radius}}$.

By this means S curves, or curves with a change of radius, can be put in, *provided* that the alteration be at one of the pins by which the curve is marked.

The offset at such a point of change is equal to the half sum of the offsets of the two curves, if the new curve be on the same hand; and equal to the half difference of same, if the new curve be in the opposite direction.

An " odd distance" at the springing may be got over by setting off at the nearest stake in the straight line, a point, by an offset calculated for its distance from the springing, and then ranging this point with *a*, &c. A point in the curve at any distance between two stakes, and the tangent at it, may be easily got.

Fig. 20.



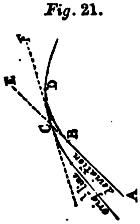
The second method is by tangents, *i. e.*, chaining along the tangents, and laying off rectangular offsets of calculated lengths. The length of any such offset, *bc*, is equal to radius $- \sqrt{(\text{radius})^2 - ab^2}$.

This method may be used on very rough ground; and, indeed, may occasionally be used where Rankine's method is inapplicable; as, for instance, in laying out a curve round a bluff precipice, with low lands, where the tangents can be laid out.

Sometimes after the line has been staked out, a deviation of part may be required.

In staking out such a deviation there is no difficulty about the starting, or about the joining in at the end, provided that at the latter point the original line was straight. If, however, the original line be curved at that point, the following case arises.

Fig. 21.



The deviation AB is being staked; required the distance BC by which the springing B may be found, so as to start the curve BD, which shall join in properly to the original curve.

Let the radius of the curve BD be r, and the radius of the old curve R.

The angle ECF must first be observed, which can be done without difficulty; let it be called θ, then

$$CB = R \sin \theta - \sqrt{R^2 \sin^2 \theta - 4 r R \sin^2 \frac{\theta}{2}}$$

B.

(*July*, 1874.)

DOCUMENTS TO BE SENT TO THE RAILWAY DEPARTMENT, BOARD OF TRADE, PREVIOUSLY TO THE SECOND NOTICE OF THE INTENTION TO OPEN A RAILWAY BEING GIVEN.

I. A copy of the parliamentary plan and section, with any deviations which may have been made during construction marked thereon in red; and with the corrections in the distances, levels, inclinations, sections of ground, and radii of curves, rendered necessary by such deviations, also marked in red; as well as the POSITIONS OF THE SEVERAL STATIONS, AND THE LENGTHS OF THE PLATFORMS; and the widths of cuttings and embankments on each side of the railway.

II. A table of gradients and level portions, with the positions of the stations distinctly shown.

III. A table of curves and straight portions.

IV. A table of cuttings and embankments.

V. A table of the bridges for roads crossed by the railway.

VI. A table of bridges and viaducts over watercourses and valleys.

VII. A table of all level-crossings, public, occupation, or private; bridle, or foot-ways.

VIII. A table of tunnels.

IX. A table of aqueducts and of culverts three feet or more in diameter.

According to the forms forwarded herewith, observing that the situations of works, &c., should be described in each by reference to the same fixed point; and that it will be convenient if the station nearest to the metropolis, for a main line, or the junction with the main line for a branch railway, be adopted as such point of reference.

X. A statement affording detailed information under the following heads :—

1st. **Permanent Way.**—Whether the line be double throughout, or partly double and partly single, or single throughout with sidings; the distances from the fixed point adopted in the tables, at which the single portions commence and terminate—or, for a single line, at which the sidings commence and terminate; whether the land has been purchased for an additional line of rails, or whether any other arrangements have been made with a view to adding an additional line at a future period; the width of the line at formation level; the gauge; the width between the lines where double; the description of rails employed, with a diagram section, their length, and weight per yard; the description and weight of the chairs, where these are employed; the mode of fixing the chairs and securing the rails; the fastenings adopted for the joints of the rails; the description of sleepers, with their smallest and average scantling and length; their distances from centre to centre if transverse, and if longitudinal, the details of any ties by which they are connected; the nature of the ballast, and its depth below the under surface of the sleepers; the description of points adopted; the number and positions of all facing points connected with the main line; and the names of the stations or other places at which engine-turntables are provided.

2nd. **Fences.**—Description of fencing adopted on each portion of the line, especially the height of the rails, and distance between posts, if post and rail; the height, number of wires, distance between supports, and means of straining, in the case of wire-fencing.

3rd. **Drainage.**—General description of the drainage employed, and if on any part of the line it has been attended with peculiar difficulty, a detailed description should be given.

4th. **Stations.**—Their names, and their distances, at the commencement and termination, respectively, from the fixed point; the gradients on which they are situated and approached; and the positions of and distances between the home and the distant-signals.

5th. **Width of Line.**—The minimum space allowed from a height of 2 feet 6 inches above the rails, between the sides of the widest carriages in use upon the railway and any fixed works, such as pillars and walls at stations, abutments, piers, supports, arches, girders, telegraph posts, sheds, &c., along the line. The minimum section of each tunnel should be appended, showing within it a section of the widest carriage to be used on the line.

6th. **Bridges and Viaducts.**—Drawings in detail of all bridges and viaducts, either over or under the railway, accompanied by sufficient information to allow of the probable strength of each being ascertained by calculation; and by sections showing the distances between the girders and the sides of the widest carriages to be used on the line, when the girders are more than 2 feet 6 inches above the level of the rails.

7th.—Diagrams of all junction and station arrangements.

XI. Carriages to be used for the conveyance of parliamentary or cheap train passengers under the Act 7 & 8 Vict. c. 85.—The following *minimum* dimensions should be observed in the construction of these carriages:—They should contain 20 cubic feet of space per passenger; the area of the glass windows should afford 60 superficial inches per passenger; the seats should be provided with backs, should be 15 inches broad, and should afford 18 inches in width per passenger; they should be provided with proper means of ventilation, and with two lamps at least to each carriage. Drawings of these carriages consist-

ing of the three following figures, to scale of not less than 4 feet to an inch, viz. :—

1. An outside elevation, showing the positions of the windows, ventilators, and lamps.
2. A transverse section.
3. An inside plan, showing the arrangements of the several seats, with references by letters, specifying the width and length of each seat, and the number of passengers to be accommodated on each; also a memorandum of the size of the windows and ventilators, stating whether they are fixed or constructed to open and close, and the positions of the lamps for lighting the carriages at night.

MEMORANDUM
OF IMPORTANT REQUIREMENTS.

1. The requisite apparatus to be provided at the period of inspection for ensuring an adequate interval of space between following trains.
2. Home-signals and distant-signals for each direction to be supplied at stations and junctions; with extra signals for such sidings as are used either for the arrival or for the departure of trains.
3. The levers and handles of points and signals to be brought close together, into the position most convenient for the person working them, and to be interlocked. The points to be provided with double connecting rods. The levers of the points to be sufficiently long to enable the pointsmen to work them without risk or inconvenience, and not to be placed on the ground between the lines of rails. All signals which are worked by a wire should be so weighted as to fly to "danger" on the fracture of the wire.
4. Facing points to be avoided as far as possible.
5. It being necessary that a uniform system of signals should be adopted on all railways, the semaphore arms should, at stations and junctions when there is more than one on one side of a post, be made in future to apply—

the first or upper arm to the line on the left—the second arm to the line next in order from the left, and so on. In the case of sidings, a low and short arm, distinct from the arm or arms for the passenger lines, may be employed. Clocks should be placed in conspicuous positions for the use of the signal-men.

6. The signal-handles and the levers of the points should be brought together under cover upon a properly constructed stage, with glass sides inclosing the apparatus. They should be so arranged that while the signals are at "danger" the points shall be free to move; that a signal-man shall be unable to lower a signal for the approach of a train until after he has set the points in the proper direction for it to pass; that it shall not be possible for him to exhibit at the same moment any two signals that can lead to a collision between two trains; and that, after having lowered his signals to allow a train to pass, he shall not be able to move his points so as to cause an accident or to admit of a collision between any two trains. The facing points should be provided with apparatus which will ensure the points being in their proper positions before the signals are lowered, and which will prevent the signal-man from shifting the points whilst a train is passing them. Every signal-man should be able to see the arms and the lamps of his home as well as his distant-signals, and the working of his points. The fixed lights in the signal-cabins should be screened off, so as not to be mistakable during fogs, for the signals exhibited to control the running of trains.

7. The junctions between passenger lines and any sidings should be protected by a home-signal and a distant-signal in each direction. The sidings should be so arranged, that the shunting carried on at them shall present the least possible obstruction to the passenger lines; and there should be a blind siding or dead-end—with the points closed against the passenger lines and interlocked with the signals.

8. When a junction is situated near to a passenger station, or is connected with goods or mineral sidings, the platforms and sidings should be so arranged as to prevent, as far as possible, any necessity for shunting over the junction.

9. When two single lines meet, the junction should in ordinary cases be formed as a double-line junction.

10. The lines of railway leading to the passenger platforms to be so arranged that the engines shall always be in front of the passenger trains as they arrive at and depart from a station; and that each line shall have its own platform.

11. Platforms to be continuous and not less than six feet wide for stations of small traffic, nor less than twelve feet wide for important stations; and the descent at the ends of the platforms to be by ramps, and not by steps. Pillars or columns for the support of roofs or other fixed works not to be nearer to the edge of the platforms than six feet. It is considered desirable that the height of the platforms above the rails should be two feet six inches, the minimum height to be one foot nine inches.

12. When stations occur on or near a viaduct or a bridge under the railway, a parapet or fence on each side should be provided, sufficient to prevent passengers falling from the viaduct or bridge in the dark. All viaducts under the railway should be provided with handrails and with projecting platforms for the protection and escape of the platelayers. Viaducts of timber and iron should be provided with manholes and other facilities for inspection.

13. The steps of staircases approaching stations, and of foot-bridges over the lines, and of foot-subways, to be not less than eleven inches in the tread, or more than seven inches in the rise, and all such staircases to be provided with efficient handrails.

14. Clocks to be provided at all stations in positions where they are visible from the line.

15. Turntables for engines, of sufficient diameter to enable the longest engines and tenders in use on the line to be turned without being uncoupled, to be erected at terminal stations, and at junctions and other places at which the engines require to be turned. Care should be taken to keep all turntables at safe distances from adjacent lines of rails, so that engines, waggons, or carriages, when being turned, may not foul other lines, or endanger the traffic upon them.

16. No station to be constructed on a steeper gradient

than 1 in 260, except where it is unavoidable. When the gradient at a station is necessarily steeper and the line is double, and when danger is to be apprehended from vehicles running back, a catch-siding, with points weighted for the siding, should be provided further down the incline than the passenger platform and goods-yard, to intercept runaway vehicles. When the line is single, a second line should be laid down, a second platform constructed, and a catch-siding similarly provided.

17. In a cast-iron bridge the breaking weight of the girders should be not less than three times the permanent load due to the weight of the superstructure, added to six times the greatest moving load that can be brought upon it.

18. In a wrought-iron bridge the greatest load which can be brought upon it, added to the weight of the superstructure, should not produce a greater strain* on any part of the material than five tons per square inch.

The heaviest engines in use on railways afford a measure of the greatest moving loads to which a bridge can be subjected. These rules apply equally to the main and the transverse girders. The latter should be calculated for the heaviest weights carried by the driving wheels of locomotive engines. (*See Note by the Author at the end of this Article.*)

19. The upper surfaces of the wooden platforms of bridges and viaducts should be protected from fire.

20. The joints of the rails should be secured by means of fish-plates, or by some other equally secure fastening. The weight of the cast-iron chairs on branch lines, or lines on which the traffic will be small and light, and where it will be worked by engines of ordinary construction, should be not less than 26lbs. each; but on main lines, and where heavy traffic may be worked at high speeds, the chairs should weigh not less than from 28lbs. to 30lbs.

* The above maximum strain for wrought-iron bridges was adopted after due investigation by, and on the authority of, a Royal Commission. Until similar investigations have been made in regard to steel, and its various qualities, by an equally competent tribunal, it is impossible to adopt rules for the strains which should be permitted in the employment of that material.

21. When chairs are used to support the rails, they should be secured to the sleepers, at least partially, by iron spikes or bolts. With flat-bottomed rails, when there are no chairs, or with bridge rails, fang- or other through-bolts should be used, at least at the joints and in some intermediate places.

22. No standing work (other than a passenger platform) should be nearer to the side of the widest carriage in use on the line than two feet four inches, at any point between the level of two feet six inches above the rails and the level of the upper parts of the highest carriage doors. This applies to all arches, abutments, piers, supports, girders, tunnels, bridges, roofs, walls, posts, tanks, signals, fences, and other works, and to all projections at the side of a railway constructed to any gauge.

23. The intervals between adjacent lines of rails, or between lines of rails and sidings, should not be less than six feet.

24. At all level crossings of turnpike and public roads, the gates should be so constructed as to close across the railway, as well as across the road, at each side of the crossing. They should not be capable of being opened at the same time for the road and the railway. A lodge or station house should be provided, as is required by Act of Parliament. When a level crossing occurs at a station, there should be a box, if there is not a lodge, at the gates, for the use of the gate-keeper. Wooden gates are considered preferable to iron gates for closing across the railway.

25. The fixed signals attached to the gates at the level crossings should be placed in convenient positions for being seen along the railway as well as along the road. When a level crossing is so situated that an approaching train cannot be seen from a sufficient distance, distance-signals (which may both be worked by one lever) should be supplied.

26. Mile-posts and quarter and half-mile posts and gradient-boards should be provided along the line.

27. Tunnels should in all cases be constructed with recesses for the escape of the plate-layers.

Note by the Author.

The Author is indebted to Lieut.-Colonel Hutchinson, R.E., for the following Rules and Tables, which may be used where there are no exceptional circumstances :—

(1.) The strength of a simple cross-girder should be equal to that calculated for the weight, evenly distributed, set opposite the span in the following table :—

	Space between Side-Girders.	Weight in tons, English gauge.	Weight in tons, Irish gauge.
Single line ...	11 feet.	15.3	14
" " ...	12 "	16.5	15.2
" " ...	13 "	17	16.2
" " ...	15½ "	19	18
Double " ...	23 "	29.2	27.4
" " ...	24 "	30.3	28.6
" " ...	25 "	31.4	29.7
" " ...	26 "	32.3	30.7

If the cross-girders be fish-bellied, the cross-section under each rail should be that calculated for the middle by this rule.

(2.) Weights on spans from 10ft. to 45ft. from heaviest engines, L. & N. W. Ry., with driving wheel at centre of span, or so placed as to produce greatest strain.

Span.	Weight at Centre.	Equivalent distributed.	Span.	Weight at Centre.	Equivalent distributed.	Span.	Weight at Centre.	Equivalent distributed.
Feet.	Tons.	Tons.	Feet.	Tons.	Tons.	Feet.	Tons.	Tons.
10	14.3	28.6	22	23.3	46.6	34	27.9	55.8
11	14.3	28.6	23	23.8	47.6	35	28.3	56.6
12	14.9	29.8	24	24.3	48.6	36	28.8	57.6
13	15.8	31.6	25	24.7	49.4	37	29.2	58.4
14	16.7	33.4	26	25.1	50.2	38	29.7	59.4
15	17.9	35.8	27	25.4	50.8	39	30.3	60.6
16	18.8	37.6	28	25.8	51.6	40	30.7	61.4
17	19.9	39.8	29	26.1	52.2	41	31.2	62.4
18	20.7	41.4	30	26.4	52.8	42	31.7	63.4
19	21.4	42.8	31	26.6	53.2	43	32.2	64.4
20	22.1	44.2	32	27.1	54.2	44	32.6	65.2
21	22.8	45.6	33	27.5	55.0	45	33.1	66.2

(3.) The weight of superstructure, side-girders, cross-girders, rails, and fastenings, planking, and ballast, may be taken for the purpose of calculating the strength of bridges of the above spans at two-thirds of a ton per lineal foot for a single line of rails.

C.

ACQUISITION OF LAND BY COMPULSORY PURCHASE.

ENGLAND.

In England the exercise of compulsory powers of purchase is regulated by the Lands' Clauses Consolidation Act, 8 & 9 Vic., cap. 18.

CLAUSE 18 requires notice to be given by the company to all parties interested, stating the "particulars" of the lands required.

This notice should state accurately the quantity and situation of the lands required for the railway works, and for greater security a plan is generally annexed to the notice, or reference is made to the parliamentary plan deposited at a specified place. If any mistake is made on the face of the plan, the company will be unable to enter on any lands which may be omitted. The annexing of a plan is not, however, prescribed by the Act.

CLAUSE 22 leaves the compensation to be settled by two justices, if the compensation claimed does not exceed fifty pounds.

CLAUSES 23 to 37 allow the parties interested to have the compensation, if the claim exceeds fifty pounds, decided by arbitration, and regulate the proceedings.

CLAUSE 38 *et seq.* prescribe the course to be pursued by the company who, if arbitration be not desired by the parties, can issue their warrant to the sheriff to summon a jury to decide, and regulate the proceedings.

CLAUSE 84 provides, that for the purpose of surveying and taking levels, and of boring, to ascertain nature of soil, and of setting out the line of the works, it shall be lawful for the promoters of the

undertaking, after giving not less than three nor more than fourteen days' notice, to enter, paying for any damage done.

CLAUSE 92 enables an owner to refuse to part with portion of a house, building, or manufactory, if he is willing and able to sell the whole.

It appears, however, that the company, if they give notice to treat for a portion only of such premises, in the event of the owner refusing to part with less than the whole, are released from the obligation of their notice.

CLAUSE 93 gives the owner power to require the company to purchase a severance of less than half an acre.

CLAUSE 94 gives the company the power to purchase severances where the expense of bridges, &c., exceeds the value.

Previous to a case coming before a jury, the engineer should be prepared at all such points. A court-house is a bad place to originate a design and make estimates.

IRELAND.

For Ireland, though the last-mentioned Act applies to the United Kingdom, there is a special Act which substitutes a different machinery for settling the differences between the company and owner of land.

CLAUSE 4 (14 & 15 Vic., cap. 70) requires the company to have made out and signed by their *secretary* and *engineer* maps and schedules of the lands required, and of the accommodation works which the company propose to make and maintain, with the names of the parties interested, and the estimated value of each and every interest.

Every such map shall be on a scale of not less than one inch to two hundred feet, and all lands and houses shall be numbered with numbers "corresponding with the numbers marked upon the parliamentary plans."

> These maps and schedules are to be deposited at the Office of the Commissioners of Public Works in Ireland.
>
> A copy of so much as is situate in any county is to be lodged with the Clerk of the Peace for that county.
>
> A copy of so much as is situate in any union is to be lodged with the clerk of that union.

The plan prepared by the engineer for the contract is the one always lodged under this Clause.

It will often be found that between the times of preparing the parliamentary and contract plans, alterations will appear on the face of the ground, involving confusion as to the "numbers."

> 1.° Fences may be thrown down, and two or more fields, bearing different numbers, may be thrown into one.
>
> 2.° New fences may have been made, subdividing what was one field into two or more.

In the first case, the engineer should mark both numbers on the plan in their proper places, and show both in the schedule bracketed to the one area.

In the second case, it is the common plan to add new numbers; for instance, if the field originally bore the number 17, then the numbers 17*a*, 17*b*, &c., would be put on the new subdivisions, *provided* these latter numbers were not in the parliamentary plans elsewhere.

This, in the author's opinion, is an erroneous practice, and likely to lead to serious complications. What should be done in this case is to place the number 17 on the contract plan in the same relative position it occupied on the parliamentary plan, and to link in each new subdivision. In the schedule, each subdivision will appear under the reference, "17 part of," being identified by the acreage marked on the plan, and entered in the schedule.

As these maps are ordered to be so lodged for the information of an arbitrator and the parties interested, it is re-

markable that the company are not bound to lodge or publish the *section*, without which, it is needless to say, any one would be quite at sea in claiming accommodation works, and in many instances in estimating the consequential injury to property.

The schedules are prepared by the company's valuator, and then carefully examined by the engineer to see that the numbers and areas are correct.

CLAUSE 5 directs the appointment of an arbitrator by the Board of Works.

CLAUSE 8. After the appointment of an arbitrator, and delivery to him of the maps and schedules, a notice of such appointment and of the lodgments as above, shall be published *once in each of three successive weeks* in the *Dublin Gazette*, and in a newspaper of the county in which the lands are situate. And a day and place for the sitting of the arbitrator shall be named, which shall not be earlier than *thirty-one* days (altered to *twenty-one* days by a subsequent Act) from the date of insertion of the last notice.

CLAUSE 9. The arbitrator having heard all parties, the company's advisers included, shall make a draft award, which shall state the money to be paid in each case, and the accommodation works to be made and maintained. The draft award shall be be deposited as the maps and schedules were, and notice of each lodgment published as the preceding notice, *i.e.*, *in three successive weeks*, fixing time and place for sitting for final award, which shall not be earlier than *twenty-one days* (altered to *fourteen days* by a subsequent Act) after the date of the insertion of the last notice.

The final award is then to be lodged in the same manner and places as the maps and schedules; it is conclusive, except it be traversed at the assizes as below.

During these enquiries a great deal of work and responsibility is thrown on the engineer.

His duty is to advise for the company in all matters connected with his department, to protest against useless accommodation works being given, which are often claimed *solely* for the purpose of afterwards being sold to the company. He must also see that accommodation works are not granted exceeding in cost the value of the land accommodated.

He should be prepared to give the arbitrator every information as to the proposed levels of the railway, drainage of proposed works, areas of claimants' farms, areas of portions severed, cost of proposed works.

For his own sake as well as for that of the company, he will endeavour to have accommodation works strictly defined in the awards. For instance, a cattle pass, if intended to be 8ft. high × 10ft. wide, should be so stated, and not merely 8ft. × 10ft. If a claimant is willing to take an under pass at his own risk as regards drainage, the company should be protected *as far as possible* by being exempted, as regards any responsibility as to drainage of that bridge, *in the award*.

If works are awarded which will require for their construction land outside what is marked on the maps, it is better to have it settled then and there, and put into the award, or a note entered that the works are subject to the ground being given.

Above all, let him guard against any responsibility being thrown on the company to either bring water to, or keep it away from, any work. The company might find that to provide "a watering place for cattle," and "a watering place with water," are two very different liabilities.

CLAUSE 26 enables parties dissatisfied with the final award to traverse it at the assizes, and claim extra money and additional accommodation works, or both.

The engineer has to attend at the assizes as adviser to the company, and as a witness.

A subsequent Act, 23 & 24 Vict., cap. 97, contains a very important clause, enabling the company, upon depositing such amount as the arbitrator may think fit, to enter on the lands *as soon as the draft award is deposited* without waiting for the subsequent proceedings.

D.

SUNDRY PROVISIONS OF ACTS OF PARLIAMENT AFFECTING THE CONSTRUCTION OF A RAILWAY.

26 & 27 *Vict.*, *cap.* 92.

CLAUSE 4. The company may deviate from the line or level of any arch, tunnel, or viaduct, with consent of parties interested in the lands, and the Board of Trade.

CLAUSE 6. The company shall erect a lodge at every turnpike or public carriage road level-crossing.

CLAUSE 7. The Board of Trade may require *at any time* a bridge to be substituted for a level-crossing.

CLAUSE 8 enables the company in such event to exercise compulsory powers of purchase of land for such bridge and approaches.

CLAUSE 9. In case of a junction with another railway, the work shall be done "under the superintendence and to the reasonable satisfaction of the engineer for the time of the company, or person to whom the other railway belongs."

CLAUSE 12. The company joined may erect "such signals and conveniences incident to the junction," as may be necessary, on the ground of *either* company.

CLAUSE 13. In carrying out any tidal works, the company shall, during construction, *and for ever afterwards*, maintain such lights as the Board of Trade may require.

CLAUSE 14. If a special act does not define space and water-way, and headway of a bridge over navigable tidal water, it shall be made as the Board of Trade directs.

CLAUSE 16. Where the works cut off tidal water or tidal lands, the company shall make such crossings as the Board of Trade may direct, *provided* that no crossing shall be for a severance already compensated for, nor interfere with the working of the railway, and the company shall not be bound to maintain the crossings.

CLAUSE 17. The centre line of a railway, skirting a navigable river, shall not be deviated so as to diminish navigable space, even within limits of deviation, except with permission of the Board of Trade, and then as the Board directs.

27 & 28 *Vict.*, *cap.* 71.,

(*Ireland.*)

CLAUSE 15. The company are bound to make good fences between their land and adjoining property. Also, to convey all water from or to the lands lying near or affected by the railway in the same manner and to the same extent as it was conveyed before the making of the railway. Owner complaining within five years may memorial Board of Works, who may appoint an arbitrator.

CLAUSE 17. The company shall execute all works ordered by arbitrator. The proceedings are similar to those in the case of compulsory purchase of land for railways in Ireland. (14 & 15 Vict., cap. 70.—*See page* 157.)

27 & 28 *Vict.*, *cap.* 121, *amended by* 33 & 34 *Vict.*, *cap.* .19

Power is given to the Board of Trade, by certificate, to authorize the construction of a railway by a company, under certain circumstances, the principal of which is the consent of *all* landowners and parties interested.

31 & 32 *Vict., cap.* 119.

CLAUSE 27. This clause empowers the Board of Trade, under certain circumstances, to sanction the construction of a railway as a "Light Railway," under regulations to be laid down by the Board.

CLAUSE 28. (1) On a light railway a greater weight than eight tons shall not be carried on the railway by any one pair of wheels.

(2) The rate of speed shall never exceed twenty-five miles an hour.

1 *Vict., cap.* 83.

Clerks of the Peace and others must allow inspection and copies to be made of all documents lodged with them at all reasonable hours, by anyone, under a penalty of £5. Fees—One Shilling for inspection, and for each hour after the first; and Sixpence for every hundred words copied.

E

ESTIMATE OF BALLYGRIFFIN PUBLIC ROAD BRIDGE.

NO.	DESCRIPTION AND DIMENSIONS.	QUANTITIES.	
	Excavation :—	c. f.	
2	Abutments, 34.0×8.0×4.6	2448	
6	Counterforts, 6.0×5.0×1.0	180	
2	Wings {[7.0×8.0×5.6]+[6.9×7.0×4.0]+ [6.6×6.6×2.6]+[10.0×5.0×1.0]}	1306	
2	" {[5.6×8.0×5.6]+[5.0×7.0×4.0]+ [5.6×6.6×2.6]+[9.0×5.0×1.0]}	1032	
2	Extra for double line, 100.0×5.0×4.6 ...	4500	
			c. y.
		9466	351
	Rubble Masonry in foundations :—	c. f.	
2	Abutments, 34.0×7.3×1.0	493	
6	Counterforts, 5.3×6.0×1.0	189	
2	Wings {[7.0×7.0×1.0]+[6.9×6.6×1.0]+ [6.6×6.0×1.0]+[10.0×4.10×1.0]}	361	
2	" {[5.6×7.0×1.0]+[5.0×6.6×1.0]+ [5.6×6.0×1.0]+[9.0×4.10×1.0]}	295	
			c. y.
		1338	49

Estimate of Bridge—*Continued.*

NO.	DESCRIPTION AND DIMENSIONS.	QUANTITIES.	
	Rubble Masonry:—	*c. f.*	
2	Abutments, 31.10×6.6×13.6	5587	
6	Counterforts, 4.0×5.3×14.9	1859	
2	Wings {[5.4×4.8×21.0]+[9.3×4.6×18.9] +[11.6×4.4×14.3]+[11.6×3.8× 9.6]+[9.3×3.4×5.3] ... ...}	5151	
4	Newels, 3.2×4.6×4.0	228	
2	Haunchings, 31.10×8.0×6.9	3438	
4	Spandrils, 2.6×10.6×1.3	131	*c. y.*
		16394	607
	Hammer-squared Work, on face:—	*s. f.*	
2	Abutments, 37.6×13.6...	1013	
2	Wings, [5.4×21.0]+[42.0×12.0] ...	1232	
4	Newels, 7.6×4.0	120	
4	Spandrils, 8.0×6.0	96	*s. y.*
		2461	263
	Hammer-squared Work, two faces:—	*c. f.*	*c. y.*
2	Parapets, 1.3×47.4×3.0	355	13
	Dressed Work, 1st Class	*c. f.*	
2	Coping of Parapets, 1.7×48.3×0.9 ...	115	
2	Coping of Wings, 57.6×2.6×0.9 ...	216	
4	Newel Caps, 3.8×3.10×0.9	42	
2	Ring-pens, 2.3×36.6×2.0	328	
4	Springers of Ring-pens, 2.0×2.3×1.3 ...	23	*c. f.*
			724
	Dressed Work, 2nd Class:—	*c. f.*	
2	Stringcourse, 2.0×48.2×0.9	145	*c. f.*
			145
	Arch Sheeting and Springers—	*c. f.*	
	[26.6×33.0×2.0]+2[26.6×2.0×1.3]	1882	*c. y.*
			70
		c. f.	
	Puddle, 28.0×50.0×0.6	700	*c. y.*
			26

F.

OPPOSITION ON STANDING ORDERS.

It may be useful to give some account of the proceedings to be taken when instructions have been received by the engineer to oppose a Bill on Standing Orders.

When the Bills for the Session have all been lodged, a list of them is made out in the order of lodgment. It is then open to *any person** on or before the 9th, 16th, or 21st January, according as the Bill is numbered, from 1 to 100, 100 to 200, or 201 and upwards, respectively, to present a memorial complaining of non-compliance with Standing Orders on the part of the promoters.

The memorial is referred to the examiners, one of whom holds an enquiry, when the memorialist or his agent attends with witnesses to prove the allegations set forth in the memorial.

If he sustains them, or any of them, the examiner reports non-compliance to the Standing Order Committee, who then consider whether the errors committed should or should not induce them to recommend the House to suspend Standing Orders, and allow the Bill to be proceeded with. In the parlance of the place, getting a Bill adversely reported on by the examiner to the committee, is termed "sending it upstairs."

The preparation of a memorial is the joint work of the engineer and the parliamentary agent; the former is responsible for the accuracy of the facts stated, as far as the allegations concern engineering; and the latter for the allegations being in proper form, and not failing in technicalities.

The first step is to procure copies of the plans and sections and Book of Reference as deposited, a copy of the Bill, and copies of the notices in the newspapers and *Gazette*, and a set of the best available maps of the district.

Generally, but not always, copies of the plans and sections will be given on application to the engineer of the

* The memorialist need not in any way be concerned with the merits of the Bill.

promoters; if not, a copy can be made at a trifling expense at whichever of the offices is nearest, at which the plans have been lodged. (see p. 3.)

The solicitor of the opponent has of course his share in the preparation of a memorial. He enquires if all the advertisements were duly inserted at the proper times that the lodgments were duly made, and in proper time, that other deposits and notices were in order, &c., &c.

The following may be read in the light of instructions, given to an assistant :—

1. Compare plans with ordnance or other maps, and see that the names of townlands, parishes, and counties are all on plan, correctly shown, properly spelt, and with correct boundaries.
2. Compare them with newspaper and *Gazette* notices, to see if they have all been inserted, and properly spelt. A surplusage in the notices is of no consequence.
3. See if the descriptions of termini in the notices agree with those in the Bill, and both with the termini as shown on the plans.
4. Examine plans carefully to see
   (*a*) if there is any *apparent* case of an enclosure without a reference number.
   (*b*) if there is any *apparent* case of an enclosure with two reference numbers.
   (*c*) if there is any reference number repeated twice in the same townland or parish, as the case may be.
   (*d*) if any mile or furlong mark be omitted.
   (*e*) or wrongly numbered.
   (*f*) or wrongly measured.
   (*g*) if any curve of a radius of one mile or less is not so marked, or incorrectly marked.
   (*h*) if the words "limit of deviation" are omitted.
   (*i*) if there is any *apparent* case of a house or garden requiring an enlarged plan which is not given.
   (*j*) if there are any discrepancies between general and enlarged plans.

(*k*) if there be a junction with an existing or authorized railway, whether the plan of same be properly given.
(*l*) if the plan be on a scale sufficiently large.

and, as regards the section, to see
(*a*) if the point to which the datum is referred is near one of the termini.
(*b*) if the inclination of every gradient is marked.
(*c*) if each is correctly marked.
(*d*) if the height at every change of gradient is marked.
(*e*) if the height so marked agrees with measurement by scale.
(*f*) if the miles and furlongs are all marked.
(*g*) if they are correctly measured and numbered.
(*h*) if the marks of the miles and furlongs on the section agree with those on the plan. The error, if existing, must be established by reference to a road-crossing or the termini.
(*i*) if the horizontal scale of section is the same as that of the plan.
(*j*) if a road, *apparently* a turnpike or public carriage road, is shown on the plan but not noticed on the section.
(*k*) if a road is noticed, but no depth of cutting or height of embankment given thereat.
(*l*) if a cross-section of a road be omitted.
(*m*) if scales of cross-sections and vertical scale of section be correct.
(*n*) if every cross-section is of sufficient length on *each* side of the railway.
(*o*) if there be any discrepancy between the cutting or embankment at a road-crossing on the general section and on the corresponding cross-section.
(*p*) if at a road-crossing on the general section it be not stated that either the level is to be unaltered, or if altered the amount of alteration.*

* No allegation can be founded on the physical impossibility of carrying out any proposed alteration or other work. It is sufficient for the examiner, that if a work *be* proposed that the proposal be properly *shown* as required by standing orders.

(*q*) if the alteration of a road as described on general plan is inconsistent with same as shown on the cross-section.
(*r*) if cross-sections of *all* road level-crossings be shown, whether altered or unaltered.
(*s*) if any cutting or embankment as measured by scale is more than five feet and not marked.
(*t*) if marked, whether incorrectly.
(*u*) if the requisite section of any existing or authorized railway with which a junction is proposed be omitted.

and, as regards the Book of Reference, to see
(*a*) if every number on the plan in each townland or parish (as the plan may be numbered) is also in the Book of Reference under the proper head.
(*b*) if every number under any townland or parish in the Book of Reference be shown on the plan in that townland or parish.
(*c*) if *apparently* the kind of property shown as that indicated by a number on the plan is the same as that described in connection with that number in the Book of Reference.
e. g. a number may be found in the Book of Reference to refer to a field, while on the plan that number is placed on what is clearly a river, or a house or a road. At *this* stage the engineer has nothing to do with what the property is *in fact*.
(*d*) if the names of all townlands, parishes, and counties are correctly spelt in the Book of Reference.

The frequent use of the word *apparent* in the above may be noticed. The engineer up to this is to see what errors there are which *declare themselves* on the face of the plans, sections, and Book of Reference; his next step is to ascertain what errors exist as *matters of fact*.

In order to ascertain these errors, assistants must be sent, first to examine if the lodged copies are true copies of each

other;* secondly, to examine the ground, and see if there are any fences, houses, or other properties, which have been omitted, incorrectly shown, or shown but which do not exist; thirdly, to level over the ground and ascertain any errors that there may be in the general section and cross-sections, particularly examining the datum point of reference, to see if it be clearly defined, immovable, and not liable to be confounded with any other point; and fourthly, to examine the ground with the plans and Book of Reference, and see if any of the descriptions as a *matter of fact* are erroneous.

It is *no* part of the engineer's business to deal with erroneous descriptions of owners or occupiers.

Having collected all the data on which to found engineering allegations, the engineer proceeds to London, and assists the parliamentary agent in the preparation of the memorial. He will there be furnished with tabular forms, on which he must correctly enter the particulars of the errors.

The heads of a set of such tabular forms are here given, they differ in each agent's office:—

1. Properties wholly or in part within the limits of deviation not drawn on the plans or described in the Book of Reference.
2. Properties wholly or in part within the limits of deviation drawn on the plans, but not numbered on the plans, or described in the Book of Reference.
3. Properties wholly or in part within the limits of deviation drawn and numbered on the plans, but no corresponding numbers in the Book of Reference.
4. Properties numbered in the Book of Reference, but no corresponding numbers on the plans.

* "The plans deposited" are strictly those deposited in the office of the Clerk of the Peace, or principal sheriff-clerk; the others are all copies. In one case, in which the author was concerned, an allegation was made as to inconsistency with "the plans deposited" in a former year; it was attempted to prove this by comparison with the "copy" in the Private Bill office, but the examiner would not allow it to be gone into, as the plans deposited in the former year with the Clerk of the Peace had not been brought to London.

5. Properties wholly or in part within the limits of deviation shown and numbered as undivided on the plans and in the Book of Reference, but which are in fact divided (*i.e.*, omitted fences.)
6. Properties wholly or in part within the limits of deviation shown and numbered as divided on the plans and in the Book of Reference, but which are in fact undivided (*i.e.*, surplus fences.)
7. Houses, &c., which are in fact separate properties, but which are included under one number on the plans and in the Book of Reference.*
8. Two properties wholly or in part within the limits of deviation bearing the same number on the plan, but only one such number in the Book of Reference.
9. Two properties bearing the same number in the Book of Reference, but only one such number marked on plan.
10. Properties appearing to be wrongly described in Book of Reference, as shown by their drawing on the plans.
11. Properties wrongly described in the Book of Reference as a matter of fact.
12. Houses or gardens wholly or in part within the limits of deviation of which no plan is given on a scale of at least one inch to 400 feet.
13. Curves, of which the radius is one mile or under, but of which the radius is not marked.
14. The same erroneously marked.
15. Errors in level at specified points.
16. Continuous errors in level between specified points.
17. Cuttings whose extreme depth exceeds 5 feet, but their depth not marked in figures on the section.
18. Cuttings whose depths are erroneously marked on the section.
19. Embankments whose extreme height exceeds 5 feet, but their height not marked in figures on the section.

* Where different parts of a house and offices are under different roofs, but owned and occupied by the same person, one number is sufficient for them, though separated into different portions on the plans.

20. Embankments whose heights are erroneously marked on the section.
21. Furlong points not, or erroneously, marked on the plan.
22. Furlong points not, or erroneously, marked on the section.
23. Rate of inclination wrongly marked on the section, ascertained by comparison of difference between vertical heights and the distance between them.
24. Rate of inclination not marked at all.
25. Vertical measures not marked on section at change of gradient.
26. Vertical measures erroneously marked.
27. Height of railway over surface of turnpike or carriage road, navigable river, canal, or railway, crossed by railway, not marked in figures on the section.
28. The same erroneously marked.
29. The height over railway of surface of turnpike or public carriage roads, navigable rivers, canals, or railways crossed by railway, not marked in figures on the section.
30. The same erroneously marked.
31. Turnpike or public carriage roads crossed by railway, with level to be altered, of which no cross-sections are given.
32. Turnpike or public carriage roads intended to be crossed by the railway on the level, of which no cross-sections are given.
33. Cross-sections of turnpike or public carriage roads shown, but which do not extend to a length of 200 yards on each side of the centre line of the railway.
34. Embankments in which a viaduct of more than three arches intervenes, but the height of one of the parts into which the embankment is divided by the viaduct is not marked.
35. Cuttings in which a tunnel intervenes, but the depth of one of the parts into which the cutting is divided by the tunnel is not marked.
36. Distances between which a tunnel is shown on the section, but the centre line for the corresponding length on the plan is not dotted.

The engineer should be prepared to prove every error in the plans by at least *two*, and every error in levelling by at least *three*, experienced assistants, who can stand cross-examination without being confused.

In case of any discordant evidence being given by the two sides as to the levels, it is not unusual for an independent engineer to be appointed to examine the allegations on the ground, and report to the examiner; but, as far as the author knows, the referee has no *right* of entry on lands for the purpose.

Errors not included under the above heads are "alleged" in special paragraphs of the memorial.

G.

SUNDRY OTHER STANDING ORDERS.

(COMMONS, 1874.)

ORDER No. 70. Provision is here made for the very unusual event of an alteration in plans or sections being found desirable after the regular lodgment in November and before the introduction of the Bill into the House. Notices by advertisements in the *Gazette*, and newspapers and lodgments of plans are required in manner analogous to those described in the beginning of this book, page 2, *et seq.*

No published maps are required.

ORDER No. 153. Under this order, in case of the proposed alteration of any road, so that the "ascent" would be inconsistent with the Railways' Clauses Act, the committee to whom the Bill, whether opposed or unopposed, is referred, if they sanction the proposed alteration, must specially report same to the House.

This S. O. concludes with the following sentence:—"Also, a good and sufficient fence, of four "feet high at the least, shall be made on each "side of every bridge which shall be erected."

Considering that there is no necessity under any previous S. O. to mention proposed heights of parapets on the plans or sections or in the Bill, it is not easy to see what is meant by this part of the Order. Nor is it easy to see why a special report should be made by the committee upon the departure of the provisions of the Bill from those of the general Act in the one particular of inclination of road approaches, and not extending the same protection to headways of bridges over roads or the widths between the abutments, with which the public are at least equally concerned.

As this S. O. applies to "every" bridge, it, of course, includes bridges carrying the railways over roads, which makes it still more puzzling. It may also be remarked that it deals only with "ascents" or approaches of bridges *over* the railway, and does not apply to "descents" for the purpose of carrying a road under the railway. The distinction between "ascents" and "descents" is clearly laid down in 8 Vict., c. 20, clauses 49 and 50.

The corresponding Order of the House of Lords requires that roads which have *ceased to be turnpike roads* "shall" have the same inclinations as turnpike roads.

The intention of these Orders seems to have been to require the Committee to *specially* report anything proposed to be authorized by the Bill in contravention of 8 & 9 Vict., cap. 20, clauses 49-52. (See p. 33.) They are worded, however, like clauses of an *Act* of Parliament the effect of which they cannot in any way have.

The *Standing Order* about roads which have ceased to be turnpike roads would have no operation in compelling the works to be executed in accordance with its dictation.

ORDER No. 154. The committee must specially report any road level-crossing which they sanction to the house.

ORDER No. 169. Every Bill shall set forth the length of each railway or tramway in miles, furlongs, chains, and yards, or decimals of a chain.

Since the first part of this book was in type, the follow-

ing new Orders of the House of Commons have been announced :—

ORDER No. 48[a] requires that, in case power is sought in any Bill to take fifteen or more houses occupied wholly or in part by the labouring classes, a statement of the number of the said houses and their occupants must be deposited in the Private Bill Office on or before the 31st December.

ORDER No. 181[a] prescribes, in the above case, that a clause be inserted requiring that, before taking the houses, eight weeks' notice shall be given.

ORDER No. 181[b]. "In every such bill, a clause shall be "inserted, if applicable, requiring the promoters "to procure, within a time to be limited, sufficient "accommodation for persons belonging to the "labouring classes, who will be displaced under "the powers of the Bill."

ORDER No. 181[c] requires the committee to specially report if such a clause has been inserted, and if not, why they decided that it was inapplicable.

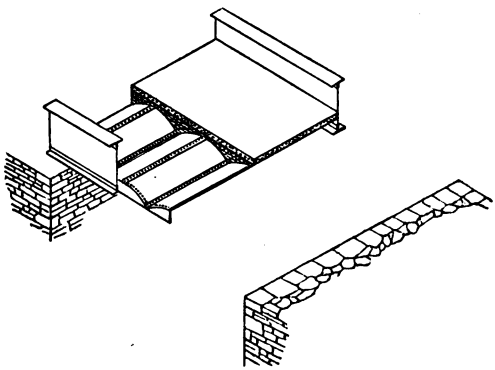
These Orders of the House of Commons follow the provisions of the Lords' Orders No. 191. (See p. 26, where the number of houses has been erroneously stated as thirty instead of fifteen.) The Lords' Order, however, only applies when *compulsory* power is sought; these new Commons' Orders apply whether the power to take the houses is by compulsion or agreement. Before this, if the company, previous to going to Parliament, had settled by agreement with the landlords of such houses, (the tenants holding at will, or on short terms), a clause might be inserted in the Bill exempting these houses from the operation of the compulsory powers and *then* no "statement" would be required under the Lords' Order; this can no longer be done.

H.

PLATFORM OF AN OVER-BRIDGE WITH CURVED GIRDER PLATES.

The author is indebted to Mr. James Price, M. Inst. C.E., for permission to insert here a diagram and short account of this method of forming the platform of an over-bridge.

Fig. 22.



The top consists of two side-girders with a series of bent plates resting on each girder. In the bridge from which the woodcut is taken, the span between the side-girders is twenty feet. The chord of the curve of each plate is six feet, and the sagitta fifteen inches; plates ⅜ inch thick.

Each plate is connected to the adjoining one by an angle iron, $4'' \times 4'' \times \frac{1}{2}''$, riveted to both, and two strengthening strips, each $5'' \times \frac{1}{2}''$, riveted along the top of the plate, one inside, the other out. Each plate, it will be seen, is practically a cross-girder, the curved plates acting in quite a different manner from those in fig. 14, p. 84.

From experiments made by Mr. Price, it appears that the breaking weight of these bent plates is fully that of a load of 9.95 cwt. per superficial foot.

Bent plates have been in use acting as girders, but rest-

ing on cross-beams at short distances apart; their application to such large spans as this, and the peculiar mode of adding to the flanges, as it were, of them by the strips above and angle irons below, is entirely due to Mr. Price.

The ends of the curved plates are riveted to a cast-iron segment-plate, resting on the girders. The top was covered with Mr. Price's patent tar asphalte, weighing 67lbs. per cubic foot, with concrete and road-paving over it.

Experiments were made on a curved plate girder, of which the dimensions were: length, 9ft. between supports; chord, 3ft.; sagitta, 7½in.; plate, ⅜in. thick; angle iron, 3″×3″×⅜″, no strip along top. From these, it appeared, that it would not give way under a loadof 32 cwt. per superficial foot.

The advantage of the employment of such a light material as Mr. Price's tar asphalte, for levelling off the haunchings of the curved girders, is apparent when the weight of concrete is considered, about 145 lbs per cubic foot. In the case of one of Mr. Price's bridges, the top of which was 60 feet × 45 feet, the saving of weight by using asphalte was 60 tons. The author has employed earthenware pipes of different sizes, laid along the haunchings, bedded in and flushed with concrete, with the same object of reducing the dead weight of the filling.

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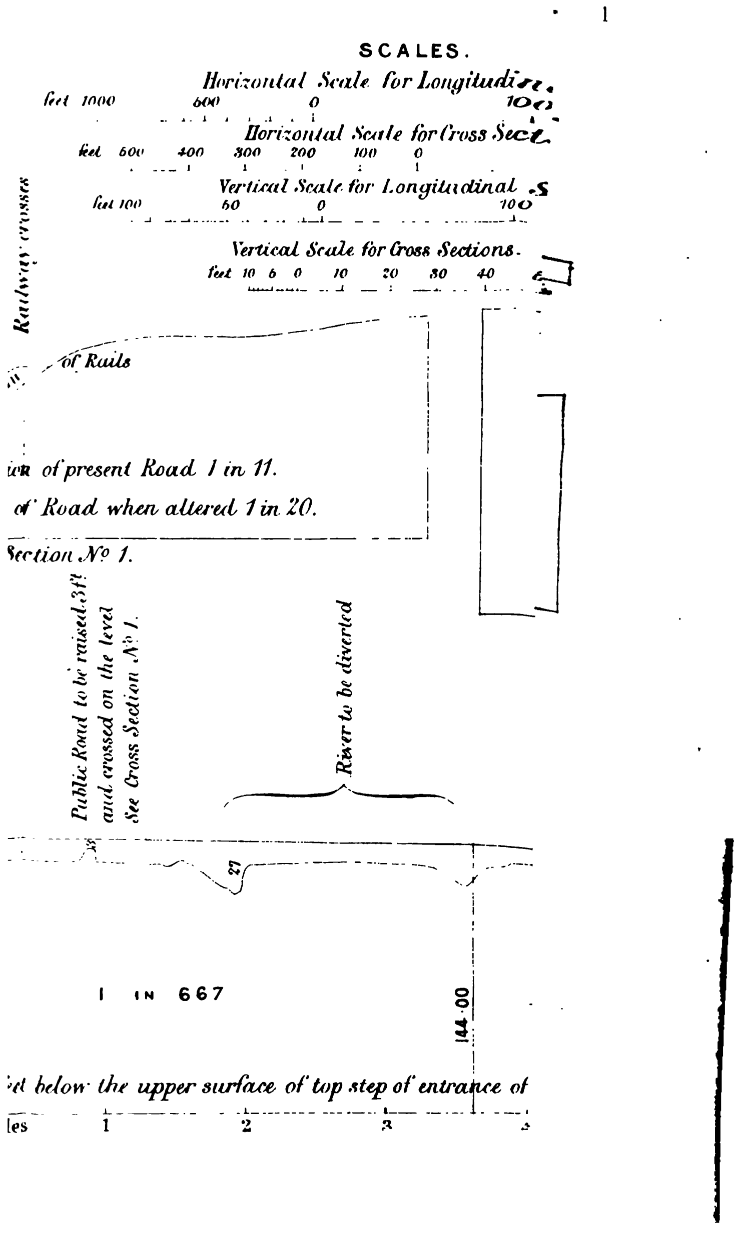
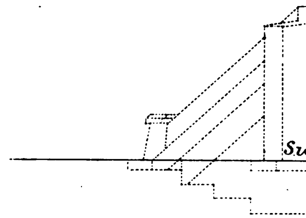
Forster & Co Lith. Dublin.


1
SCALES.
Horizontal Scale for Longitudi
feet 1000 600 0 100
Horizontal Scale for Cross Sect
feet 600 400 300 200 100 0
Vertical Scale for Longitudinal S
feet 100 60 0 100
Vertical Scale for Gross Sections.
feet 10 6 0 10 20 30 40
Railway crosses
of Rails
of present Road 1 in 11.
of Road when altered 1 in 20.
Section No 1.
Public Road to be raised 3ft and crossed on the level
See Cross Section No 1.
River to be diverted
27
1 IN 667
144.00
below the upper surface of top step of entrance of
les 1 2 3

4
7



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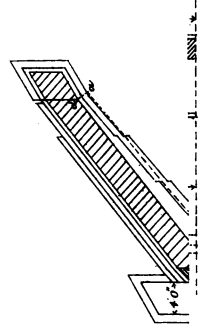
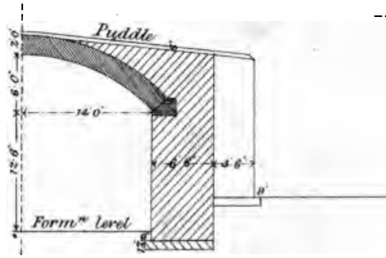


AT STRINGCOURS

SECTION OF ARCH AND ABUTMENT



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SCALE

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